ZOÖLOGY

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ZOÖLOGY

A TEXTBOOK FOR COLLEGES AND UNIVERSITIES

BY

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Dedicated

TO THE MEMORY OF THOSE WHO DIED
THAT WE MIGHT HAVE A CHANCE
TO MAKE A BETTER WORLD

Vitae Filum

To live, to grow, to work, to love,
Shall earth below or heaven above
Ask more of thee?
Thus holding fast the golden thread
Which joins the living and the dead
Through all eternity!

CONTENTS

INTRODUCTION

THE problems which mankind is compelled to face are at once old and new, — much older than man himself in so far as they are the problems of life, and growth, and reproduction; yet ever new, since mankind progresses, and creates for itself conditions which have never existed before. There are two reasons why we cannot safely go back to even the wisest of the ancients, to get from them adequate counsel for the direction of our modern life. One is, that we are no longer situated as they were: after two or three thousand years of development, our modern society necessarily presents many complex features of which they knew nothing, and could not have foreseen. The other is, that we represent the maturer age of our species, with accumulated knowledge and records of experience behind us — knowledge and experience dearly won, and constituting a precious guide to conduct. The mature man looks back with pleasure and longing to the days of his boyhood, but he does not appeal to his boyish thoughts for the guidance of his later life. Yet the ancient and modern meet as the result of the most recent researches. Paradoxically, the discovery of innumerable details, the revelation of undreamed-of complexities, leads us back to a better conception of the essential simplicity of nature. Natural law, the underlying unity in the midst of diversity, stands more clearly revealed today than ever before, and we are nearer than we ever were to a true philosophy. Thus we appeal to the totality of existence, past and present, and every fact has its place in our system, and teaches some lesson. The mind, however, is limited in its powers, and for practical purposes it is necessary to

digest and condense the results of research, and thereby provide a short cut to the fruits of the labor of generations. At the same time the educational process is not complete unless the student has patiently trodden some path of discovery of his own, and has thus come to appreciate the methods of science. In a democratic society, no citizen can afford to remain ignorant. The democracy of this country still remains largely an ideal, only to be realized when the average level of intelligence has been raised through education. We are like young persons expecting to inherit a great estate, to the management of which we must bring the best powers we are capable of developing. The essential facts of biology, the science of life, should surely be known to all, and we believe that some course embodying them should be obligatory for every student. If this is granted, some revision of current methods appears to be required. The biology or zoölogy for the average individual who has no thought of specializing in the department should not be too morphological, too rich in detailed facts of structure and classification. Experience shows that such minutiæ are not remembered, and do not necessarily leave as a residue any broad and useful conceptions. The working out of a single problem or small group of problems in detail is a different matter, as it teaches of methods and points of view in a manner never to be forgotten, and may well open the way for an amateur interest which will remain a blessing through life.

On the other hand, we cannot shirk the essential problems because they are hard. Each generation of men has to wrestle with the angel, and deal in some manner with matters which it can never more than

partly understand. From a psychological and pedagogical standpoint, it is surely an error to suppose that each idea must be luminously clear at the moment of presentation. Our deepest beliefs, our most profound convictions, have been attained gradually, and we thank our elders for early revealing to us the existence of puzzles which required half a lifetime for us to solve. A student may conceivably fail outright in a course and yet have laid the foundation of a brilliant discovery. There was doubtless humbug in the ancient mysteries, as there is in many modern ones; yet mystery is not all humbug, and important mental syntheses may require years for their development. With the modern loosening of the hold on religion, the feeling of awe may atrophy in a world too superficially regarded and too cheaply explained.

The thread of our narrative is broken at intervals by biographical chapters. We are too apt to receive the gifts of science without asking whence they came. It is well, therefore, to learn something of the lives of those who have made discoveries or organized scientific work. What we have today was not gained without arduous toil and persistent zeal, often in the face of many difficulties. As the pious studied the lives of the saints, so may we pause now and then to learn how scientific heroes have won new territory for the kingdom of science. Thus, if we have anything of generous response within us, we may return to our studies refreshed, resolving that we also, in some measure, will further the good cause.

T. D. A. C.

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ZOÖLOGY

CHAPTER ONE

THE PHYSICAL UNIVERSE

The laws of nature

1. In the vast expanse of the known universe, the materials composing the stars are essentially the same as those found upon the earth, and the forces governing their movements do not differ from those which may be noted and tested in any laboratory. Thus physical nature possesses a unity which is more striking the more we inquire into it, and what we call the "laws of nature," our statements of how things happen, are considered to be valid everywhere. This uniformity of action extends not only through space but also in time, so that after sufficient experience of natural phenomena, man is able to predict events far in the future, and assert the occurrence of others in the remote past, in spite of the absence of any contemporary records. To the unscientific it seems miraculous that an astronomer could say to his little son, wondering at the sight of Halley's Comet in the sky: "If you live to be a very old man, you will see that comet again, but I shall never see it"; and that the boy should have lived, and come to old age, and seen the comet appear in the very year predicted. Such a prophecy is one of the commonplaces of modern astronomy, but it could not be made were not the "laws of nature" valid throughout the ages.

Limitations of the human mind

2. It must not be supposed, however, that scientific men have discovered all the important facts. The philosopher understands by the term "reality" the totality of what exists,—all the phenomena of the

universe, many of which can never be examined by our human senses. The limitations of our perceptions are well shown when we realize that the vibrations or waves which give us the sensations of light, sound, or electric shock are only a few of those which must exist. The ultra-violet light, which we cannot see, we can determine by its chemical effects, and no physicist doubts that there are innumerable vibrations which we cannot detect at all.

The nature of truth

3. Yet the known and unknown facts are so related that the known part of nature is in a sense a fair sample of the whole. The unknown does not continually disturb the known in unexpected ways, and when it does so, it is usually brought into the region of the known. Its nature is calculated from the character of the disturbance. The scientific man has to deal with "truth," and by truth he means not the absolute reality of the philosopher, but such reality as he has been able to test and examine. He does not absolutely know that the "laws" deduced from the experience of mankind will always be found valid, but the mass of accumulated experience is such that he finds he can rely upon them. This is especially true in the realm of physics.

LIFE

The uniqueness of life

4. Modern science tends to emphasize the uniqueness of life, in spite of the fact that vital phenomena are said to be "explained" by laws of chemistry and physics. The ancients imagined life, in some form or other, to be as widely diffused as heat or light, and saw in the starry heavens a region peopled by innumerable sentient human beings. Today, while

we do not know what forms of spiritual existence may be possible, we can positively state that life, in the ordinary acceptance of the word, is possible in only an infinitesimal portion, relatively speaking, of the universe. It is practically certain that the earth is the only planet of the solar system which can support life, as we know it. Even if we assume (it is pure assumption) that there are other systems wherein life exists, the whole life-bearing surface must be so small a part of space that it cannot be expressed in intelligible mathematical terms. There are also good reasons for limiting the duration of life, so that its existence on any globe belongs to only a minute fragment of the time which the astronomer recognizes as representing the minimum required for the evolution of the universe. Life, then, is the most unique and exceptional phenomenon, or group of phenomena, in the material universe; and had it been possible for a scientific being to study nature prior to or outside of the existence of life areas, he could hardly have predicted or expected living beings, much less those conscious of their own existence.

Matter and energy

5. Asking how life originated, and what it is, we must first determine the conditions under which it is manifested. The physical universe is said to consist of matter, but this "matter" is known to us only through its manifestations of energy, all of which consist of movements during time, through space. These movements may be gross and visible, or excessively minute, such as those producing heat, or bringing about chemical changes. Although an object such as this book may be said to be stationary, as it rests upon the table, its minute particles are actually in motion. The totality of matter is said to be constant, and also,

necessarily, the totality of energy; but this energy may cease to produce any appreciable phenomena without being destroyed. Physicists suppose that conceivably the whole universe might (or, some say, will) "run down," so that all its energy will be in forms producing no chemical or physical "phenomena," and thus practically non-existent from a human standpoint. No one knows how such an inert universe could be started up again, but the translation of energy from latent to active forms is familiar, and without it there could be no life. Life exists because oscillation or alternation between the two states of energy is possible.

CHAPTER TWO

THE LIVING SUBSTANCE

1. LIFE, as we know it, is manifested only by *protoplasm.* This protoplasm, or primal material of life, is a translucent, jelly-like substance, seeming on inspection to have no definite structure. The amount occurring in a single mass is, however, quite limited; the protoplasm of the living body is broken up into innumerable separate though contiguous units, called the *cells.* **Protoplasm the living material**

While we speak of the living material as protoplasm, the word must be understood to indicate not a single sort of substance, but a whole class of substances differing in minute though very significant details. The protoplasm of man is not the protoplasm of the worm or flower; yet it is convenient to have a single word to designate all living material, which, however diverse in details, is fundamentally similar in all cases. This essential similarity has been strongly emphasized by recent experimental work, which shows that it is possible, up to a certain point, to reason from the life phenomena of plants to those of animals, or vice versa.

2. What, then, is this protoplasm? It is a mixture of complex chemical compounds, consisting of carbon, oxygen, hydrogen, nitrogen, and other elements. Such a statement conveys little to the mind, especially if we recall these elements in their pure form — carbon as charcoal or diamond, the other three as invisible gases. A chemical analysis may give us all these elementary bodies, in certain proportions, but we are scarcely more edified than we should be if shown the paints out of which a splendid picture had been made. **Chemistry of protoplasm**

Chemistry, however, has much to teach us about protoplasm. In chemistry the ultimate particles of the elementary substances are known as *atoms* (we are not now concerned with the still smaller *electrons*), and these atoms may be combined in definite systems to form *molecules*, which are the least possible particles of compounds. Thus water consists of hydrogen and oxygen in chemical combination, the molecules having two atoms of hydrogen to one of oxygen. The water atom is comparatively simple, and is very *stable;* that is, it does not readily fall apart, and thus lose its peculiar properties. It will be noted that the properties of a compound cannot be readily deduced from the properties of the elements of which it is composed; thus water has no particular resemblance to oxygen or hydrogen. We are therefore not surprised that the complex compound protoplasm is not like carbon or any of the elementary gases derivable from it on ultimate analysis.

Protoplasm a dynamic system

3. The protoplasm molecules, composing the smallest possible particles of this substance, are known to be of extreme complexity, so that in comparison with the water molecule they are, as it were, richly furnished palaces as compared with a hut. So complex are they, that it has been impossible as yet to construct a formula representing the composition of any one of them, as may be done for most of the molecules known to chemists. With this *complexity* goes *instability*, so that protoplasm is constantly in a state of change, the molecules gaining and losing substance. They are therefore *dynamic* systems of atoms, not *static* like the water molecule. This power of changing, of being the seat of *processes*, and therefore the cause of *phenomena*, is fundamental to life; but it alone would not suffice.

The dead body is the seat of rapid change; it falls apart, loses its identity. This is precisely what the living substance does not; it has the marvelous power of *retaining its identity as a system*, though all its actual atoms may be lost and replaced by others. We are reminded of a river, which looks the same from day to day, though the water passes by. This ability to retain its character in the midst of change applies not merely to protoplasm in the broad sense, but also to all the myriads of particular kinds, of which, as we shall see, many coexist in the same individual. Thus this ever changing substance (in one sense) is so stable (in another sense) that it may continue almost unmodified for millions of years, while mountain ranges are raised up or worn away. This we know by comparing the fossil remains of animals and plants with their modern representatives. The ancient protoplasm itself has not been preserved, but the exact forms of creatures of bygone ages are often clearly represented in the rock, and we can rest assured in many cases that their living substance was similar to that of existing types.

Carbon compounds

4. Students of chemistry recognize *inorganic* and *organic* chemistry. So-called organic chemistry is the chemistry of those carbon compounds which were formerly supposed to stand in a class by themselves, being produced by living beings, or derived from the products of such. As carbon is only one of the numerous elements, the study of its more intricate compounds might seem to be a very small branch of the science; but as a matter of fact it is a very large part of chemistry, and the most complex and difficult part. The carbon atom has quite unique properties, and its power of combining with other atoms is such that it

readily forms the basis of extremely complex and diverse molecules. It is therefore peculiarly fitted to enter into the living substance, and so far as we know, without it no life would be possible.

Proteins

5. When we are regarding the materials of the living body from a chemical standpoint, we speak of *proteins*, and recognize that within the protoplasm of a single cell there are various kinds of proteins. Thus it is not only true that the protoplasm of different animals and plants differs, but that of any one individual, or of any one of its cells, is far from uniform. Different species may indeed have in their make-up many of the same kinds of living materials, the specific difference being due more to the particular combination than anything else. Thus the words composing this sentence are all different though they contain various letters in common.

Complexity of proteins

6. The proteins are broken down by the chemist, so that they lose their original characters, and of course their relation to life activities. The process is similar to that which occurs in the digestion of foods in the body. They do not go to pieces all at once, but are reduced by a regular series of steps to what are known as *amino-acids*. These amino-acids are of very many kinds. Emil Fischer has endeavored to climb up the stairway, as it were, toward the complexity of the living stuff. It has long been known that many organic compounds could be produced *synthetically* — that is, put together — in the chemical laboratory. Fischer was able to go so far as to produce polypeptids, which are combinations of amino-acids. Theoretically, it might seem merely a matter of time and patience to get the very substance of protoplasm constructed, but probably the difficulties are insuperable.

In consequence of the complexity of the living cell, it would be necessary to construct not one substance, but a whole series of them, and then put them together in such a way as to construct a living machine.

Cessation of life activities without death

7. Suppose we could construct a cell, in all respects like that of a living organism: would it be endowed with life? Could our scientific Pygmalion expect to see his Galatea live? No certain answer can be given to this question, but there are reasons for suggesting the affirmative. Experiments have been made, in which seeds and spores have been kept for considerable periods at the extremely low temperatures known to modern physicists, temperatures at which the very air is liquefied. It is to be supposed that at these temperatures all life activities, however subtle, must stop; the machine is absolutely at a standstill. In spite of this, on the return to normal conditions, vitality is unimpaired. This being the case, we may probably argue with reason that the extremely low temperature which inhibits all change would, if maintained, preserve the material indefinitely, leaving it ready at any time to take up life activities when suitably warmed and moistened. Such permanent cold storage would be found in the vast abysses of space, where conceivably minute spores might circulate for ages, until they chanced to fall upon a suitable planet. In some such way the earth may have received its life; but if so, we are still no nearer to solving the problem of the origin of life itself.

Colloidal nature of protoplasm

8. The physics of the cell is no less interesting than the chemistry. Protoplasm is said to be a *colloid* (from the word *kolla*, meaning "glue" in Greek), a name given to substances which diffuse slowly in liquids and do not form true solutions as do *crystalloids*,

such as sugar or salt, with which they are contrasted. The terms refer to states or conditions rather than to substances, but a number of important facts are connected with the colloidal nature of the living material. Guyer defines protoplasm as an aggregate of colloids holding water for the most part, and in this water crystalloids are held in solution. Now such colloids may be more or less solid or liquid, and when they reach the more solid condition they are spoken of as *gels*. Protoplasm, in the living state, undergoes such changes, and these are *reversible*, so that the two states may alternate indefinitely. It is supposed that many of the visible phenomena of the cell are due to conditions of gelation. Heat or poisons may act so severely on the protoplasm that an *irreversible* gelation results, when death at once ensues. We are reminded of elastic substances which lose their elasticity on being subjected to too severe a strain.

Irritability and stimuli

9. One of the most striking properties of protoplasm is its *irritability;* that is, its power of responding by movement of some kind to a *stimulus*, which may arise externally or internally. This disturbance or stimulus may be physical or chemical, but the essential point is that the living material does not merely transmit the wave of energy, as an iron bar may transmit heat, but displays characteristic movements of its own. Irritability, in a biological sense, includes all such responses. Thus, if you meet a friend, who smiles in response to your greetings, he is exhibiting irritability in the sense now employed. In the lower forms of life this irritability is more or less general, and the paths of disturbance are indefinite; but in higher animals there is a definite nervous system, and through it messages are very rapidly transmitted to and from the

brain. It has been suggested that the transmission of a nerve impulse may be connected with a wave of gelation sweeping along the nerve, an almost instantly reversible change in the density of the material. If this is true, there is some analogy with the transmission of sound in air, the sound "waves" representing temporary conditions of density. Darwin, when experimenting with that remarkable insectivorous plant, the sundew (*Drosera*), found that if one side of the leaf received a stimulus (e.g., caught a fly), the sensitive hairs on the other side moved after a time. During the interval, he noted that a wave of cloudiness passed across the leaf, apparently a condition of temporary or reversible gelation. This activity was prevented by such anæsthetics as ether or chloroform, and if their action on the nerve tissue of animals is analogous, we can understand how their effects are produced.

Energy of the living substance

10. The colloidal particles of the living substance, each consisting of many molecules, bear electric charges. They are immersed in or surrounded by water, containing dissolved materials which themselves bear positive or negative charges of electricity. The whole forms a system in which attraction and repulsion, and therefore gelation or liquefaction, depend upon electric states. When particles of a colloid are brought together, or when they are driven apart, as the result of electric forces, new states are produced, leading to fresh changes. Thus, without going into further details, we gain some idea of the physical phenomena implied when we say that living protoplasm is a dynamic system of atoms and molecules. We also see how the life processes are dependent upon the presence of water and of non-living matters in solution; in other words, the protoplasm molecules, though the exclusive

seat of life, cannot carry on their functions except in a special environment. From the standpoint of pure physics, it becomes impossible to separate rigidly the processes or displays of energy of the living material from those going on in the immediately adjacent medium; indeed, the whole combination really displays the activities which we call vital.

The fact that water, in a liquid state, is necessary for the manifestation of vital activities, greatly restricts the possibilities of life in the universe. If we make a table of the known temperatures, from the cold of space to that of the hottest stars, the portion of it on which we mark water as liquid seems almost infinitesimal; yet it is within these narrow limits that the manifestations of life must occur. It is true, as we have seen, that temperatures below the limit do not necessarily injure the vital machine; but those above the boiling point cause irreparable damage. Gelation occurs which is irreversible, and the rhythm of life has departed.

The vital rhythm

11. Life, then, is rhythmic; summer and winter, day and night, the rise and fall of each successive generation, the beating of the heart, the reversible states of the living colloid, the dance of the atoms and electrons, everywhere in nature we see the swinging pendulum which marks the passage of time. No wonder that music appeals to us irresistibly, and that in decorative art beauty is gained by the repetition of a theme. As Bergson insists, our deepest convictions arise out of the very nature of life itself.

CHAPTER THREE

THE CELL AND ITS ACTIVITIES

1. LIVING creatures are either single cells, or are made up of aggregations of cells. The word "cell" is rather misleading; it was given many years ago to those plant cells which take the form of a little compartment or box, containing a fluid. Such cells are rigid, sometimes large enough to be seen with a hand lens without difficulty. We now know that the hard wall, the box, is composed of *cellulose*, which is not part of the living material, and that the essential thing is the protoplasm which it incloses. Not only are all plants cells or groups of cells, but the same is true of animals. In animals, however, there is no stiff wall of cellulose, though there is commonly a thin membrane, and the distinctness of the cells is much less evident on inspection. Since we recognize the fundamental similarity of plant and animal cells, we use the same word for both, and think of the living unit rather than anything inclosing it. Our definition is thus entirely changed, and comes to be: *a cell is a particle or unit of protoplasmic material, which exhibits all the essential phenomena of life.* It consists, of course, of innumerable molecules which, taken by themselves, would not function as living things. Such a cell may exist apart from others, as in the Protozoa or one-celled animals. There is a relation between the nature of the cell wall and the activities of the organism; the essentially stationary plant has stiff cell-walls, but in the mobile animal most of the cells are necessarily flexible. The function of a muscle cell, for example, is connected with its ability to change its shape. **The cell**

Cell life and individual life

2. In protoplasm the molecule is composed of innumerable atoms, the colloid particle of many molecules; the cell, of multitudes of these colloid particles. System within system, they all function as a unit; and the individual animal or plant, made up of millions of cells, also behaves as a single machine. Nevertheless, the cell is a definite unit of life, and its individuality is not lost in that of the creature of which it forms a part. During the life of the individual, cells are born and die; every time we wash our hands, dead skin cells, so small and flat as to escape observation, fall away. In the blood are active cells known as *leucocytes* (Greek for "white cells") or white blood corpuscles, which crawl about with a flowing motion, looking like certain free single-celled animals (Protozoa) which are found in the water of ditches (Fig. 1). These leucocytes may be taken from the body, and if kept in a nourishing solution at the right temperature, continue to live as independent beings. Still more remarkable is the fact, recently discovered, that portions of a living body, composed of highly specialized cells, may be cut off and isolated, and under suitable conditions will go on growing for an indefinite period. No one can deny life to such isolated particles; yet the admission compels us to recognize that the "life" of a man is composite, and is in a true sense the

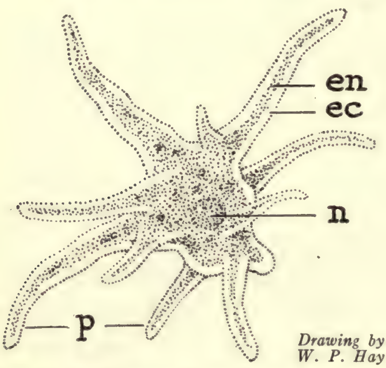


FIG. 1. Amiba, one of the Protozoa; an example of a free-living cell, occurring in ponds and ditches. *n*, nucleus; *en*, *ec*, inner and outer protoplasm; *p*, pseudopodia.

summation of the lives of innumerable cells — somewhat as the life of a town or a school is the aggregate of the lives of its members. The life of the body differs from the life of the town or nation in that it is much more completely socialized; the parts or individual cells work in more complete harmony, and are under more accurate control by the governing power which has its principal seat in the brain. In spite of this, disturbances often occur, and the disease called *cancer*, in which a group of cells runs riot, growing without proper relation to the rest of the organism and without developing even the necessary means for its own maintenance, represents anarchy in the corporate system. Cancer tissue is not capable of entering into coöperation with the rest of the body. When we say that human *life* is composite in the manner described, we do not infer that human personality is without its proper and definite unity, though the study of *psychology* exhibits to us wonderful complexities of personality, connected with bodily states and with the diverse activities of the nervous system. With this, however, we are not just now concerned.

3. Since cells are true units of life, they exhibit all the essential vital functions. That is to say, they react to stimuli, they build up and break down, and finally they reproduce. The origin of new cells is always from the division of preëxisting ones, so far as we have any knowledge; *reproduction is division.* No man can make a cell, nor can he say how one came into existence. Professor T. C. Chamberlin makes the ingenious suggestion that prior to the appearance of bacteria (decay-producing germs) it may have been possible for a series of carbon compounds to evolve, leading up to those complex enough to be the seat of **Evolution of life**

life; whereas in our modern world this is impossible, owing to the destructive attacks of minute organisms. The suggestion is that life, having once evolved, will tolerate no repetition of the process. However this may be, it is everywhere recognized as a matter of experience that every new cell, and therefore every new life, arises from other life already existing. The theory of *evolution* is merely an extension of this conception, postulating that *all* life has thus arisen, and might be traced back, had we all the data, to some common ancestor in a very remote past. The sameness and unity of life phenomena lend support to this doctrine.

Continuity of life

4. If it is true that all life arises from other life, it necessarily follows that the stream of life is continuous, there is no break between generations. At no point, from the beginning many millions of years ago, — if we may postulate such a beginning, — to the present moment, has the sacred flame of life which burns in us ever gone out. In a sense we are many millions of years old, and have witnessed the story of evolution from the beginning. Yet we must die. What is death, that great contradiction of life's fundamentals? Are we to add death to the phenomena of the cell, to complete its list of vital functions by this final negation of all of them?

Reproduction

5. The answer to this question is not to be left to speculative philosophers or to theologians. It is determined by observation. The continuity of life from generation to generation is an observed fact, and it is only possible because certain cells, at least, do not die. The problem takes on a new aspect, however, when we note that the animals which consist of one cell, the Protozoa, reproduce by dividing, and *both parts live.* There is no dead body. Woodruff, after raising

thousands of generations of the slipper animalcule, Paramecium, concludes that, as Weismann long ago assumed, these creatures are potentially immortal, and do not even require the supposed stimulating effect of conjugation — the union of the protoplasm of two individuals. The fact that under natural conditions myriads die from accidental causes or disease has no bearing upon the question. We are obliged, in the face of this evidence, to strike off death from the list of phenomena necessarily accompanying life, and therefore exhibited by every cell.

Why we die

6. Yet we must die, and the innumerable cells composing our bodies must die, excepting only those which go to form a new generation. Early in the development of the individual, certain portions of the protoplasm are set aside to form the germ cells, whose function it is to start a new generation. On this fact Weismann developed his theory of the *continuity of the germ protoplasm, or germ plasm*, the living material which is passed on from parent to offspring. This germ plasm does not make any muscles, or nerves, or other body structures while it is waiting for the time when it will take part in the formation of a new individual. The other cells, on the contrary, divide many times, and the final result is muscle cells, and nerve cells, and connective tissue cells, and so forth. This specialization of the cells is necessary, in order that they may do the work required in a highly organized body; but as a result they are rendered quite unfit for reproduction. They have sacrificed the potentiality of new life for the sake of becoming specialists. The body as a whole has bought all those powers and qualities which make it man rather than protozoan, at the price of having to die. The race, however, does

not die; it continues by those germ cells which, remaining inactive and biding their time, at length come forth to defeat the forces of death.

Samuel Butler, in his fantastic story "Erewhon" (anagram of "Nowhere"), states that the Erewhonians believed that the soul of man was not immortal, but that the universe was peopled by potentially immortal beings, who need never die unless they were born into the world. These beings, it was held, were aware that death would eventually follow birth, but such was their desire and curiosity to know what it was to be alive, to be actual living people, that they could not resist. They were willing to accept death as the price of that precious experience. This fantasy now turns out to embody a truth, and it is an actual fact that death is the price of the higher life.

Metabolism 7. Cells also build up and break down; the living cell maintains its identity, yet is constantly in a state of change. Biologists have invented certain terms to use in referring to these activities. The changes going on in the cells, and consequently in the body, are spoken of in general terms as *metabolism*, with the adjectival form *metabolic*. Thus we say, the body exhibits metabolism, or the metabolism was intense, or the metabolic processes led to such and such results. This word "metabolism" covers a great many things, and for more exact (though still vague) definition we speak of *anabolism*, the processes tending to build up the body, and *katabolism*, the processes connected with tearing it down, expending its energies for the performance of work. Roughly, these distinctions are like those between saving and spending. Naturally, one cannot spend without having accumulated, but at any particular time; one or the other process may

be the leading one. During the period of growth anabolic tendencies are uppermost; females, on the whole, are more anabolic than males, since they save not only for themselves, but for a future generation. Male insects, in particular, may be short-lived and intensely active when they become adult — rapidly spending, as it were, the accumulations of their earlier life.

Food

8. In accordance with these general principles, the cell takes in and gives out substances — solid, liquid, or gaseous. It is nourished by food. This food may be of various kinds, but it is not identical with the living protoplasm of the cell. Even when one animal eats another alive, the victim is reduced to non-living material of a relatively low grade before it can be utilized as food. This food material is not put together to form new cells; it is built into the existing cells, bit by bit, as infinitesimal particles. So only may the cells grow, and the body grow by the increase of material in cells which consequently divide to form new cells. The process of thus taking in material and making it part of the living stuff is called *assimilation*, or "making like." Thus it is that the cells already present at any time control the future growth; without their aid, nothing avails.

Diverse functions of cells

9. Material is given out by the cells, as a result of their metabolism. Carbon dioxid (CO_2), a stable or static compound of carbon and oxygen, is the result of a kind of combustion, in the course of which energy is "liberated"; that is to say, appears in the form of work or heat. This matter will be dealt with later in connection with respiration. This carbon dioxid is a gas, but there are also fluid and solid products of cells. The bone cell entombs itself in a limy deposit. The

fat cell is entirely given over to the production of an oily substance. The cells of the stomach wall secrete small quantities of hydrochloric acid, which in greater amount would be a violent poison. All cells give rise to waste products, the results of their katabolic processes. In general, we speak of the waste products as *excretions*, of the useful products as *secretions*. The marvel is, that different cells, all nourished in essentially the same way, can secrete entirely different substances, acid or alkaline, solid or liquid, according to their appropriate function. The mother's milk and the poison of the snake are equally products of cell activity.

Limitations to the powers of cells

10. So astonishing is this power of cells to take up ordinary nourishment and out of it elaborate the most extraordinary and unique substances, that we are prepared to believe that their ability is wholly independent of the character of the food. This is not really the case. No cell can change one of the chemical elements into another, or produce a secretion containing a particle more of a given element than was contained in the food. Thus, for instance, if the food of babies is deficient in the element *calcium*, which goes toward the formation of the hard parts of bones, the result is the condition known as *rickets*. The man who dilutes the milk may be responsible for rickety children, whose bones become bent and deformed, because they are deficient in lime. An abundance of other substances will not make up for the deficiency.[1]

[1] Certain authors state that rickets is not due so much to deficiency of lime in the food, as to an abnormal state of the body in which the lime is not adequately deposited. In the absence of lime-containing food, the body can produce no lime; but under certain conditions, though it is supplied, it is not properly utilized.

Many years ago the baby lions in the London zoölogical gardens died in numbers in spite of the fact that the animals were well housed and given expensive food. In Dublin, where conditions were not supposed to be so good, the young lions lived. It turned out that the death of the London lions was owing to a rickety condition of the base of the skull, and this in turn to a deficiency of lime in the milk of the lionesses. This deficiency appeared to be owing to the fact that the beasts had been fed on good cuts of meat, with too little bone. In Dublin, where they could not afford to treat them so well (as they considered it), they gave them more bone and less meat, with the good results already mentioned. Thus, while the cell can do marvelous tricks of conjuring, there are limits to its powers.

CHAPTER FOUR

THE TISSUES

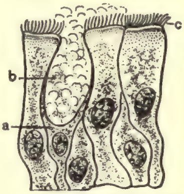
Organs and tissues

1. THE animal body consists of more or less distinguishable parts or *organs*, having characteristic functions. These organs are made up of *tissues*, which are aggregates of cells of particular kinds. As we survey the different groups of animals, we observe that the organs essentially correspond throughout long series. Thus even a fish has eyes, nostrils, and mouth corresponding with those of man. Coming to the tissues, we observe even closer similarities, and are obliged to conclude that the kinds of tissue were mostly evolved quite early in the history of life. In spite of the astounding diversity in the form of living beings, the hundreds of thousands of species, the materials of which they are made show comparatively little diversification. An enumeration of all the known types of tissue does not require much space. It is, of course, true that the similar tissues of diverse animals are not exactly alike; but they are of the same general character and behave in analogous ways, so that we classify them under general headings, and find that one description will suffice to indicate their main features. The following account is based primarily on the tissues of man.

Epithelial tissue

2. Approaching the animal from the outside, we meet first with the *epithelium*. This may be defined as surface tissue, but the surfaces which it covers may be external or internal. The outer covering or skin is continuous with the more delicate lining of the mouth, and that in turn with the surface of the windpipe and gullet. The epithelium may consist of a single layer of cells, as in the intestine, or of many layers, as in the skin. The absorbent surface of the intestine is necessarily thin;

but the skin, protecting the body from the buffeting of the outer world, requires, as it were, several lines of defense. The outer layers are continually being worn away, but others are beneath, ready to take their place. Epithelial cells are of two principal types, squamous or scale-like and columnar or column-like. Squamous cells are easily obtained for examination by gently scraping the roof of the mouth. The surface layers of the skin, or epidermis (*epi*, upon, *dermis*, the skin), are also flat, the outermost cells becoming horny as they lose their vitality. In the intestine the cells are columnar, and also in the trachea or windpipe, where they have in addition a covering of cilia on the exposed surface. These cilia, moving somewhat like the oars of a boat, are very fine protoplasmic threads of no great length. Their activity depends upon the life of the cell, not upon that of the whole organism, and they may be seen in motion under the microscope after removal from the body. Their function is to convey upward to the mouth the innumerable fine particles of dust which exist in the air we breathe, and adhere to the moist surfaces of the air passages.



From Ritchie's "Human Physiology"

FIG. 2. Cells from the lining of the trachea. *a* is a cell that manufactures sticky mucus (*b*) in which dust and germs from the air are caught. The cilia (*c*) on the other cells beat upward and sweep the mucus, dust, and germs up out of the air passages and lungs.

Ciliated cells of the trachea

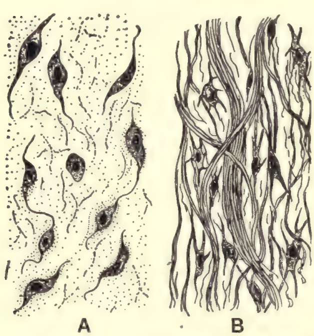
Horns and antlers

Horns are special developments of epidermal tissue, characteristic of certain hoofed animals. The horn core of the ox, which is a bony extension of the skull, is covered with true horn of epidermal origin; and hence the horn when removed is hollow, and may be used by Little Boy Blue and others to produce a sound. The antlers of deer are outgrowths of bone, and are thus

quite different from horns. A corn (Latin *cornu*, horn) is a horny thickening of the epidermis in response to pressure; an expression of a tendency which has resulted in various useful adaptations, but which in this case is distinctly injurious.

Connective tissue

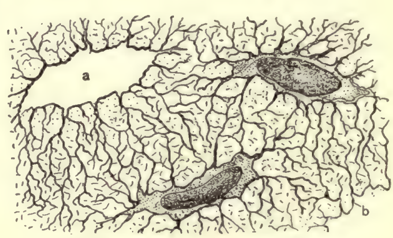
3. The term "connective tissue" is used in a general sense to include the inner framework of the body, or more specially and accurately to denote the fibrous material which unites the various cells and groups of cells much as cellulose does in plants. It does not, however, arise from the other body cells, nor is it secreted by them; it consists of special cells of relatively primitive type, with their secretions, modified to serve mechanical ends. It is probably because connective tissue cells remain in a relatively unmodified condition while nerve and muscle cells are becoming exceedingly specialized, that they are capable later on of assuming so many different forms and functions. They may produce elastic or non-elastic fibers,



A B

From Ritchie's "Human Physiology"

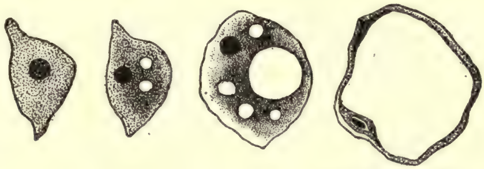
FIG. 3. Connective tissue. In its first stage connective tissue is a group of cells which build around themselves a mass of jelly-like material, as shown in *A*. This material hardens into the fibers that are seen between the cells in *B*. All through the body a framework of connective tissue runs, holding the cells, organs, and tissues in place.



From Ritchie's "Human Physiology"

FIG. 4. Bone cells. These much-branched cells deposit around themselves bone material (*b*), thus building bones to support the body. The bone cells build a network of fibers like dense connective tissue and then fill the spaces between the fibers with hard mineral matter. *a* is a cavity from which the bone cell has been removed.

or cartilage and ultimately bone, or store up oily material and become fat. Or again, they may develop **Fat cells**



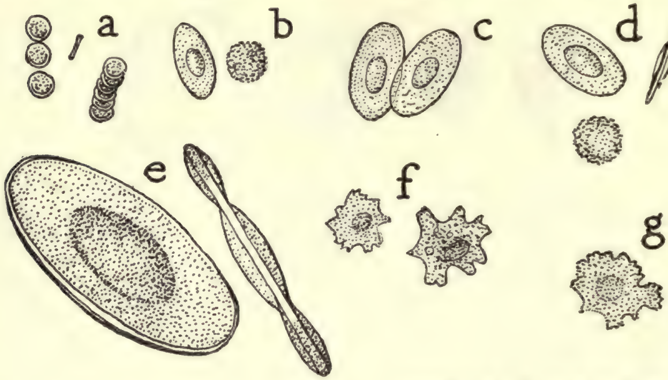
Drawing by R. Weber

FIG. 5. Development of a fat cell. The black spot is the nucleus. The original cell is of the type of connective tissue cells. Globules of fat are developed in the cytoplasm; these run together and increase, until at last the whole cell is a mass of fat with a thin outer covering consisting of what is left of the cytoplasm, the nucleus pushed to the wall. In this way material is stored up in the body, to be utilized later as a source of energy. Sometimes cells whose normal function is not that of forming fat behave in a similar manner. The result is *fatty degeneration*, a very serious disease. Pathological (diseased) states are often due to developments which in another place, or at another time, would be normal and beneficial; just as crimes are often actions which under other circumstances would be desirable. The perversion of functions is a great source of evil.

abnormally, and produce tumors (Latin *tumor*, a swelling) dangerous to life. In general terms it may be said that connective tissue cells have special powers of producing or secreting substances which serve mechanical ends, or, in the case of fat, afford a means of storing up fuel to be later utilized by the body. The material they use is derived from the food, but they have the power of selecting the raw materials and converting them into what may be fairly termed manufactured products.

4. It is contrary to familiar usage to call the *blood* a tissue, yet from the standpoint of the physiologist it cannot be otherwise considered. In cartilage we have a number of cells, separated by a solid substance. In blood we similarly have cells, but they are in a fluid medium, the *plasma*. It is necessarily so, since the blood flows, serving as a means of communication between the various parts of the body. The blood vessels **Blood**

are the streets through which traffic has to pass, in order that every part may be served with the food and



Drawing by W. P. Hay, after Perrier

FIG. 6. Blood corpuscles of various animals. *a*, human red blood corpuscles; *b*, red and white corpuscles of the pigeon; *c*, red corpuscles of a frog; *d*, red and white corpuscles of a snake; *e*, red corpuscles of Proteus; *f*, colorless corpuscles of a sphinx caterpillar; *g*, colorless corpuscle of a river mussel. All magnified to the same degree.

oxygen necessary for life, and the waste materials may be removed. The principal cells of the blood are known as the red and white corpuscles, the former vastly more numerous. The red cells, which appear pale yellowish when seen singly, are the carriers of oxygen. The white cells, really colorless rather than white, are capable of motion in the manner of simple Protozoa. They have been called the policemen of the blood, because they attack and devour injurious bacteria and other particles. They are more efficient perhaps than the policemen of our streets, since they execute sentence and effectively dispose of the criminal at the moment of making the arrest. This process is called *phagocytosis*, and is regarded as one of the important ways of protecting the body from disease. It is, however, less important than was formerly supposed, since the blood-fluid (serum) it-

The leucocytes or white cells

self often kills the bacteria; while on the other hand the white cells are not always able to destroy the bacteria, even by devouring them. There are reasons for thinking that the white cells may secrete a substance poisonous to bacteria, and thus destroy them without consuming them.

Muscle tissue

5. *Muscle* is the tissue concerned with movement, which may be either that of a part of the body, as the heart, or that of the whole organism. There is, of course, a great deal of movement going on, as, for example, that of absorption, which is not controlled by muscle; but the gross and obvious movements are nearly all muscular. Muscle cells are elongated, like very slender worms attached together in bundles. Their function is, of course, to contract, which they do in response to a stimulus. This is not in itself a special function of these cells; the primitive one-celled amiba also contracts under suitable conditions. The muscle cell, however, has the same sort of relation to an amiba that an express train has to a person walking along the road. The walker does many things which the train does not, but the train is extraordinarily specialized for *going*, and for going in a particular way along a particular track, under the control of an engineer. In the case of the muscle, the engineer is the nerve.

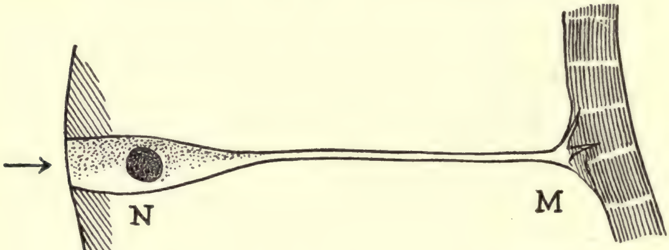
Voluntary muscle

Those muscle cells which are under voluntary control are striated, showing fine cross-lines in the manner of a file. This is equally true in vertebrate and invertebrate animals. Unstriated muscle is not under the control of the will; such, for example, is the muscle which causes the movements of the intestine. The distinction here made is not absolute, however, for the heart muscle is striated. The fibers of the heart are in fact somewhat intermediate in structure between the two great classes

just defined, but it is fortunate for us that they require no effort of the mind to call them to activity. It must also be said that even the typical voluntary muscles carry on most of their work with, as it were, only general instructions from the nervous centers. In walking or writing, for instance, we are wholly unaware of the details of muscular movements, though we will the operations in a large and general sense. Reflex centers, uncontrollable by the will, often dominate the movements of so-called voluntary muscles.

Nerve tissue

6. *Nerve* tissue has to do with the conveyance of stimuli along definite paths. The old primitive generalized response is modified in such a manner that messages are flashed from the surface to the brain or spinal cord, and thence back to the muscles of the part affected by the stimulus, in much less time than it takes to tell about it. Psychologists have determined by actual experiment that the transmission is not in-

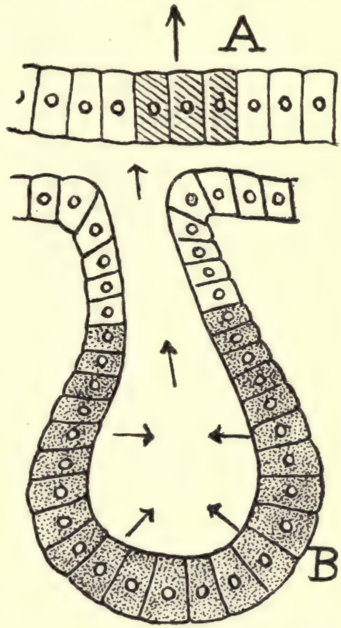


Drawing by R. Weber

FIG. 7. Diagram of a nerve cell. M = muscle-fiber. N = nucleus. The arrow indicates the direction of the external stimulus. The disturbance set up is communicated along the nerve-fiber, as along a telegraph wire, to the muscle-fiber, which thereupon contracts. The muscle is in the interior of the body, but is able to react to events going on outside. The diagram illustrates a very simple type. In the higher animals the usual course of events is different. The impulse is communicated to the brain or spinal cord, and the central nervous system sends out a call through an *efferent* (out-carrying) nerve for action. Volition comes into play, and reactions may be controlled by the will. Thus it is possible by an effort to avoid sneezing.

stantaneous; it takes an appreciable and measurable time. Formerly it was supposed that the *nerve fibers*, which seem to present no cellular structure, were not parts of cells. We now know that the nerve cell, with its nucleus, is prolonged into fiber-like extensions, reminding us of the pseudopodia of the amiba, but vastly longer, and permanent. Bundles of these fiber-like filaments constitute the nerves. The general property of irritability is here greatly accentuated, and the impulse is capable of being conveyed to other kinds of cells, which act in consequence of it. So far we seem to be dealing with nothing more than an extreme modification of primitive functions, but when we come to regard mental phenomena, especially as found in man, we enter upon a new field. The power of *memory* may be theoretically explained as analogous to that of the phonograph; a path of disturbance has left its record in the brain. When we come to *conscious-*

Nerve cells



Drawing by R. Weber

FIG. 8. Diagrams of gland cells, in section. The arrows mark the outflow of secretions. *A* represents the simplest case, in which three cells (shaded) are capable of secreting some substance, which is poured out on to the surface of the body. In *B* the gland cells secrete into a pocket or tube, which is capable of holding the material until it is wanted, as in the case of the saliva or the secretion of the stomach (gastric juice). This makes it possible to furnish at a given moment much more of the secreted substance than the cells could supply without notice. In plants the gland cells are often situated on a knob or prominence or at the end of a hairlike structure, thus reversing the structure of the tubular gland.

ness and *reason* we appear to transcend all rational explanation; the intellect, powerful though it may be, cannot understand itself. It is better frankly to admit our ignorance than to clothe it in words which sound learned but mean little.

Glands

7. *Gland* tissue, consisting of the cells secreting the saliva, gastric juice, sweat, etc., is a modified form of epithelium, in which the functional significance is entirely altered. These cells, like many of the connective tissue group, take up material from the blood, and from it produce special substances according to the kind of gland. The closed cavities of the body are lined with glandular epithelium, secreting serum. The largest gland in the body is the liver; developing from a pocket or depression in the wall of the alimentary canal, it assumes great complexity, both in external features and minute structure. The pancreas and kidneys are also glands, but the latter serves to *excrete* waste products from the blood, instead of producing a substance to be subsequently utilized. Physiologically speaking, secretion and excretion are not essentially different; but in the former case the product is utilized, in the latter it is waste.

Excretion and secretion

CHAPTER FIVE

RESPIRATION

1. We ordinarily think of respiration, or breathing, as the process of taking air into the lungs. The air we thus breathe consists of various gases, principally *nitrogen* and *oxygen*. The oxygen, approximately one fifth of the whole, is the part used in respiration. Although nitrogen is an important constituent of protoplasm, the nitrogen of the air cannot be taken up by the animal body. It serves to dilute the oxygen, and the body is so constructed that the particular mixture forming the atmosphere near the surface of the earth is best suited to its needs. This relationship is called *adaptation*, and it is obviously the body which is adapted to the atmosphere, not the atmosphere to the body. **Adaptation to the atmosphere**

2. Respiration, however, does not necessarily require lungs, or any visible process of breathing. It is common to all living beings, cells or individuals, plants or animals. Life requires free oxygen, which in animals is obtained from the air. Green plants are able to make sugar or other carbohydrates (containing carbon, hydrogen, and oxygen) from carbon dioxid (CO_2) and water (H_2O), and in the process free oxygen is liberated. Lower plants, yeasts, and bacteria are able to bring about *fermentation*, in which oxygen-containing molecules are broken up. Thus, in one way or another, all living cells get access to oxygen, though they may live in the absence of air, as do the *anaërobic* (Greek, "living without air") bacteria. The higher plants have innumerable *stomata* (Greek, *stoma*, "a mouth"), little apertures in the surfaces of the leaves, through which air, containing small amounts of carbon dioxid, is able to enter. **The use of oxygen**

Forms of energy

3. Why should free oxygen be so necessary? It is needed for the process known as *oxidation*, in the course of which energy is released or made manifest. Students of physics speak of *potential* or latent energy, and *kinetic* or active energy, states which may alternate, while the sum total of energy remains the same. When energy becomes potential, it is just as though matter were to disappear into a fourth dimension of space; it exists, but cannot be appreciated. The conception of potential energy is thus in a sense metaphysical, but the ordinary experience of mankind makes it commonplace when we recall the lifted weight, the bent spring. We know very well that when we lift a 10-pound weight a foot, we expend or use a definite amount of energy; and that if we set the weight upon a shelf it will stay there, ready to liberate the same amount of energy at any time by falling on our toes or otherwise. The agent which disturbs the weight — knocks it off the shelf — does not make the energy, but only sets it free.

Work

4. The oxygen unites with carbon, forming the very stable or static compound known as *carbon dioxid*, with the chemical formula CO_2. This is a gas, heavier than air, and is given off through the respiratory apparatus. Carbon and oxygen have a *chemical affinity* for each other, and from the standpoint of the present discussion may be compared to the weight and the earth, attracted together by gravitation. The falling weight and the uniting atoms display kinetic energy, and work results. The word "work," in biological discussions, is used in the broadest sense, to describe all the life activities; so that even a sleeping person is said to be doing work, or at any rate the organs of his body are. The beating of the heart is only an obvious

example of what is going on in every part, and the essential feature of all is *movement.*

Modification of energy

5. If kinetic energy is displayed as movement, it need not be of a gross or visible character. Much of it takes the form of *heat*, which we may be able to feel, but cannot see. It may appear as *light*, even in the living animal, such as the glowworm (a beetle), which produces a bright light with amazingly little expenditure of energy. Or again, it may be represented by *nerve impulses*, conveying messages to and from the brain; or by *muscular contractions*, enabling us to work in the more ordinary sense of that word. The oxidation process therefore provides the power which runs the machine, and without it life activities cease.

Combustion

6. When we try to define oxidation, the first obvious thought is that it is *combustion.* When coal burns in air, the carbon and oxygen unite, carbon dioxid is formed, and energy is liberated to warm us or to run an engine. In modern chemistry the matter is more closely defined, and the term *oxidation* has come to include a certain type of reaction, no matter whether oxygen is present or not. It is a reaction in which there appears to be a transfer of electrical particles or electrons, and thus we come back to the alternation of electric states as the source of the dynamic properties of the living substance. At this point we are near the limit of our present knowledge, and proceeding thence, science will probably make notable gains in the not distant future.

Oxidation of foods

7. When oxidation takes place, something is *oxidized* or burnt. The source of the oxidized material is the food, but not necessarily directly and as such. When yeast causes alcoholic fermentation, grape sugar

($C_6H_{12}O_6$) is broken up, and the oxygen momentarily liberated combines with carbon to form carbon dioxid, while the residue (C_2H_6O) is alcohol. In this case the process is simple, direct, and rapid, but ordinarily it is quite otherwise. Various substances may be taken into the body and oxidized without previous change, to a greater or less extent. This is true of alcohol, and this is why it has been claimed that alcohol has a certain food value. The more typical foods, however, are those materials which are broken up or reduced and then built up into the living substance itself. This is the anabolic process, and the opposite or katabolic process is that in which this living material is oxidized with the production of work in the sense already defined. Thus we finally see that respiration has to do with the life activities of every cell, and the conception of it as taking place merely in the lungs is quite erroneous. Breathing is seen to be merely a means directed toward a respiratory process which is going on all over the body.

Blood a carrier of oxygen

8. There is plenty of evidence showing that the oxygen absorbed by the lungs is not all used up in those organs. The red corpuscles (red only in mass) in the blood contain a substance called *hemoglobin*, which readily takes up oxygen, but also readily gives it up. The corpuscles, circulating with the blood, carry the oxygen to every part of the body. Much, though by no means all, of this oxygen is set free in the smallest vessels, and the blood returning to the heart in the veins contains less oxygen and correspondingly more carbon dioxid, the product of combustion. The difference in color of the blood is connected with these changes; the arterial blood, rich in oxygen, is bright red; the venous blood, dark purple.

Adaptive changes

9. Since respiration is an essential, vital function, we find many beautiful adaptations connected with it. The body is suited to what may be called normal conditions, but under special circumstances it has the power of adjusting itself to a certain extent to the environment. Thus Dr. E. C. Schneider and others made experiments on Pike's Peak, Colorado (14,109 feet above sea level), and found that at this high altitude the rate of blood flow was increased from 30 to 76 per cent, and the number of red blood corpuscles in circulation was very appreciably increased. Obviously such changes would facilitate the carriage through the body of the diminished supply of oxygen, and thus make up for the disadvantages of the rarefied atmosphere. Such plastic adaptations, if we may so call them, have of course their basis in the structure of the organism, just as in the case of an automobile constructed to run on "high" or "low."

Evolution of breathing apparatus

10. The evolution of the respiratory apparatus in diverse forms is very interesting. In the lowest animals oxygen is merely absorbed through the surface of the body. These animals being aquatic or parasitic, the oxygen obtained is that dissolved in the fluid, usually water, in which they live. The amount required may be small, but differs in different forms; thus coral animals flourish only where the water is in motion, near the surface, especially where there is surf. The tumbling waters inclose many bubbles of air, and some of the oxygen is dissolved. Many aquatic animals, as mollusks (Fig. 66, page 249) and various insect larvæ (young of May flies, etc.) possess external gills, which are branched processes of a delicate nature, rich in blood vessels. These take up oxygen, but in some cases serve the needs of the animals only under special environments. Thus May fly "nymphs," as they are

called, get along very well in running streams, where fresh water, with its oxygen, is constantly passing by. Brought into a laboratory and placed in a dish of water, they die overnight of suffocation. In the amphioxus and the lower vertebrates we find a notable advance of structure, the development of gill arches.[1] The new plan enables the animal to cause a current of water to flow through the gills, thereby giving all the advantages of a running stream, even when the surrounding water is quiet. The next great advance is connected with the discovery of the land. Land life implies the breathing of air, and yet it is not possible to do this without some sort of moist chamber, in which water will be constantly present and the delicate blood vessels will not be in danger of desiccation. In the insects and their relatives this end is gained by the system of *tracheæ*, branching tubes connected with small openings, or *spiracles*, on the sides of the body. In the higher vertebrates, and also in most of the land snails, the structure takes the form of one or more sacs, known as *lungs*. Lungs in the vertebrates are in pairs, and in the lowest forms are simple, moist cavities. In warm-blooded animals, which have to maintain a constant temperature, and are generally very active, the need for oxygen is greatly increased. This cannot be met by a corresponding increase in the size of the lungs, which would assume the dimensions of balloons; so there arises instead an amazing complexity, which gives an enormous increase of surface for absorption, without any great addition to the external dimensions of the organ. The spongelike tissue presents a vast number of little cavities, into which air enters, and through the walls of which gases pass.

[1] Young lungfishes and amphibians, and some adult amphibians, have external gills.

CHAPTER SIX

THE INDIVIDUAL

1. We always think of the individual as the natural unit of life. The very word implies indivisibility in the sense that the whole is something different from a mere aggregation of its parts. This idea is not without support from analogy. The atom, the molecule, even the cell, — each possesses this property of individuality. They do things as wholes, which their parts could not do separately. They behave as machines, the several parts of which coöperate for a common purpose. Surely the individual animal or plant also so behaves; is a workable machine, a whole which may not be divided without destroying its characteristic functions. **The individual a unit of life**

The fact that reproduction is division has no bearing on the argument. We have seen that in the many-celled animals the reproductive cells are set aside, and are not part of the machine, except in an indirect sense. Therefore it is reasonable to say that the production of young is no infringement on the wholeness or individuality of the parent.

2. Nevertheless, upon further inquiry, it becomes hard to define the individual in a biological sense. It would be simple to say that the individual is the product of a single fertilized egg cell. This is ordinarily but not necessarily the case. Dr. Jacques Loeb made some experiments with sea-urchin eggs, placing them soon after fertilization in sea water greatly diluted with distilled water. In this mixture the eggs took up so much water that their enveloping membranes burst and part of the protoplasm escaped in the form of a globule or drop. The eggs were then returned to normal sea water, and in due course developed. When the ex- **The individual hard to define**

truded drop of protoplasm had become entirely separated, both it and the portion left within the membrane developed, producing two individuals from what was a single fertilized egg. When the drop was not completely separated, a double monster was produced, a pair of individuals joined together.

Identical twins and double monsters

3. The sort of thing which happened in Loeb's experiment occasionally occurs among the higher animals without any intentional disturbance. Calves or chickens have two heads or more than the normal number of legs. Even in man we have such cases as that of the famous Siamese twins — two individuals connected by a band of living tissue. It is not so generally understood that this process of division, carried to completion, gives rise to what are called "identical twins." Such twins, always extraordinarily alike, and of the same sex, are due to the division of a single zygote or fertilized cell. They have exactly the same inheritance, and are thus of great interest to biologists because they afford a means of testing the effects of environment, which is the variable factor, the other being constant. According to the suggested definition of the individual given above, they are parts of the same individual, although of course no one really so considers them.

Poly-embryony

4. This division of the fertilized cell not only occurs under experimental conditions and as a rare "accident," but in certain animals is a normal occurrence. There are certain minute insects which regularly exhibit *polyembryony*, the zygote splitting up into a considerable number of individuals. Professor H. H. Newman has shown that in the nine-banded armadillo of Texas polyembryony regularly occurs, four individuals being produced by a fertilized egg cell. These, as in the case of identical twins, are always of the same sex and very

much alike. They differ to the same extent that the two sides of any single individual may differ.

Processes of regeneration after injuries

5. The question of the individual may be discussed from another standpoint. When we accidentally knock off a small piece of skin, the wound heals; but if we lose a finger, no new finger grows in its place. A lizard, however, may lose its tail, and a new tail grows. If the tail is broken at one side, sometimes a tail begins to grow at the point of fracture, and two tails result. Going to a lower level in the scale of animal life, we find that the arm of a starfish, removed with a certain amount of the disk, will grow new arms and eventually form a whole starfish. Many of the lower invertebrates may be divided into two or more parts, and each part

FIG. 9. *Renilla*, a compound animal, living in the sea (Phylum Cœlenterata, Order Alcyonaria).

will regenerate what it lacks, producing a whole individual. This is not the division of ordinary reproduc-

tion, not even a normal budding process, but a violent tearing apart of the individual, the parts of which continue to function nevertheless. A man cannot be so treated, and survive; but there is every transition between the process of healing in a wound and that of complete regeneration of two individuals upon division.

Colonies of polyps

6. The individual is elusive also in those lower forms of life which exist in groups or colonies, such as the zoöphytes or hydroid polyps. These animals occur in numbers on a common stem, through which nourishment passes. On account of this arrangement it is possible for the individuals to assume very special functions, some for feeding, some for defense, others for reproduction. Are they really separate "persons"? In spite of their intimate union, they must be so considered, and indeed in many species the reproductive persons at length float away as independent organisms.

Human personality

7. All these considerations show how difficult it is to define the individual in biological terms; yet we have no doubt about the "oneness" of our personality. There is a side to this question which transcends biological reasoning; but the biological facts, so far as they go, are of the highest significance.

CHAPTER SEVEN

MENDELISM

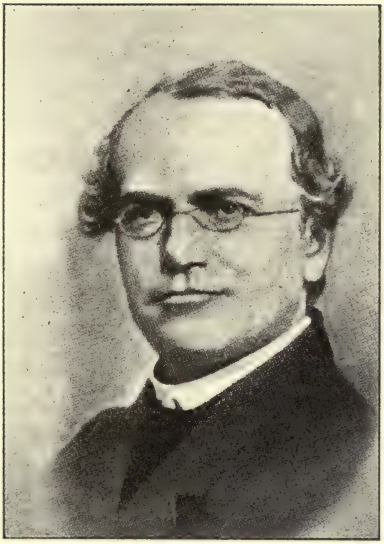


FIG. 10. Gregor Johann Mendel, at about the age of 40.

Life of Gregor Mendel

1. GREGOR MENDEL was born on July 22, 1822, in Austrian Silesia. As a boy he so distinguished himself in school that his parents decided to give him unusual advantages, though at considerable sacrifice to themselves. His younger sister contributed part of her dowry that he might continue his education. The result was that, instead of becoming a farmer like his father, he was admitted into the Augustinian house of St. Thomas at Brünn, where he was expected to take part in the educational work of the institution. In 1847 he was ordained a priest. As a teacher he was so successful that at the expense of the cloister he was from 1851 to 1853 sent to the University of Vienna, where he studied mathematics and the natural sciences. He studied under the entomologist Kollar, and in 1853–1854 published two short papers on insects. Returning to Brünn, he not only continued his teaching, but carried on experiments with plants and honeybees. Although it is known that his experiments in hybridizing bees were quite extensive, the results were never published and have apparently been lost.

Fortunately his work with plants, which led him to the remarkable generalizations now everywhere associated with his name, was described at some length in papers communicated to the natural history society of Brünn. Mendel's originality and sagacity were shown at the very beginning of his work, in his selection of plants with which to work. The problems which interested him were those of inheritance, and he saw that it was necessary to find plants which possessed constant and easily recognizable differentiating characters, but which would, nevertheless, cross without any marked impairment of fertility in successive generations. It was also desirable to find a species which could be easily grown, and would not be too liable to cross-fertilization by insects, which would of course spoil the statistical results. The greatest discoveries in science have usually been made with the most commonplace materials, and in this case Mendel chose for his principal investigations the ordinary cultivated pea, in its several common varieties.

Mendel's guiding principle in crossing plants

2. Mendel worked for eight years with his peas, and when he came to publish his results, he stated his guiding principle as follows:

"Those who survey the work done in this department (of hybridization) will arrive at the conviction that among all the numerous experiments made, not one has been carried out to such an extent and in such a way as to make it possible to determine the number of different forms under which the offspring of hybrids appear, or to arrange these forms with certainty according to their separate generations, or definitely to ascertain their statistical relations. It requires some courage to undertake a labor of such far-reaching extent; this appears, however, to be the only right way in which we can finally reach the solution of a question, the importance

of which cannot be overestimated in connection with the history of the evolution of organic forms."

Although Mendel modestly implied that any one who might survey the past work would arrive at the conviction mentioned, it was in fact due to his quite exceptional and extraordinary insight that he was able to put his finger on the weak point in previous investigations, and plan others according to "the only right way" to resolve the difficulties and uncertainties surrounding the subject. We have here a beautiful example of the scientific method, — not working at random, but following a carefully thought-out plan, developed after a full consideration of what was previously known.

Study of particular characters in peas

3. In order to carry out the experiments planned, it was necessary to choose varieties of peas which differed in some marked characters, and cross one with another. Thus the ripe peas may be either smooth (or with only shallow depressions) or angular and wrinkled; they may be green or various shades of yellow. The pods may be deeply constricted between the seeds, or lack this character. The stem may be short or long. These and other characters were readily observed, and it was noted that they represented opposites, as smooth or wrinkled, green or yellow, tall or short, etc. Mendel now crossed plants having such opposite characters, and watched the inheritance of *these particular characters*, not especially concerning himself with the other parts or peculiarities of the plants.

Dominant and recessive characters in crosses

4. At the outset Mendel noticed that the offspring of his crosses were not intermediate between the parents. On the contrary, in respect to the characters studied, they closely resembled one or the other parent. Of each pair of opposing characters, one appeared in the offspring, the other being absent. Not only this, but

all the plants resulting from a cross were alike in this respect, and it made no difference which was the seed and which the pollen parent. Thus, on crossing smooth-seeded with wrinkled-seeded varieties, only smooth-seeded plants were produced. Plants from green seeds crossed with those from yellow seeds gave only plants with yellow seeds. Tall with dwarf gave only tall. The character which thus appeared Mendel called *dominant;* the other, which disappeared, *recessive.*

Discovery of the three-to-one ratio

5. When the plants resulting from such crosses were crossed together, or produced seeds by self-fertilization, the next generation showed both the dominant and recessive characters, without any intermediates. After elaborate statistical studies, Mendel discovered that the numerical relations between the two sorts in the grandchildren of the original cross were substantially constant, following what appeared to be a definite law. Of every four individuals, on the average, three showed the dominant character and one the recessive. Although the immediate parents had exhibited no trace of the recessive character, it reappeared in apparently pure and uncontaminated form in one fourth of their offspring.

Allelomorphic or alternative characters

6. Mendel did not stop here, but continued his experiments, breeding together the plants obtained as just described. He found that when the extracted recessives (as they are called) were bred together, they gave *only* plants showing the recessive character, no matter how many generations were produced. With the dominants it was different; some gave only dominants, and others again split up into dominants and recessives, in the proportion of three to one. It was eventually determined that of the three dominants, one came pure, while the

other two split up. Thus, of the whole series of grandchildren exhibiting the 3 to 1 ratio, half, when bred together or self-fertilized, came true, and half gave 3 to 1 again. The half coming true consisted of one dominant and one recessive out of each four; the other half, of two dominants.

In discussing such experiments, we now call the original cross, or parental generation, P; the following, or filial generations, F_1, F_2, F_3, etc. It must not be forgotten that these terms are purely relative; the P represents the F_1 of *its* parents, the F_2 of *its* grandparents, and so forth.

The characters which act as opposites in inheritance, in the manner described, are said to be *allelomorphic.*

Determiners, which in development give rise to characters

7. The principal facts brought out by the experiments have now been described, but how may they be explained? Mendel observed that the characteristics studied were inherited as units, and when he used plants having *two* pairs of opposite characters, he saw that the inheritance of one pair was independent of the inheritance of the other. That is to say, there was no connection between size and the color of the seed, or between the color of the seed and its smooth or wrinkled surface. There was a connection between the color of the seed coat (white or gray to brown) and the color of the flowers, however. Obviously the inherited thing is not a particular color or size or surface, but something which so acts in development as to produce these effects. This something, which may be called a *determiner*, may produce only one visible effect, or many. In the examples cited in the preceding paragraphs there was only one effect considered or noted for each determiner. Of each pair of opposites only one can appear in a given individual; but if there are several

pairs, A–a, B–b, C–c, etc., then A is just as likely to occur with B as with b, and B with C as with c.

Modern research has shown that while the simple cases recorded by Mendel are typical, there are numerous exceptions, which are explained by various extensions of the theory, without at all contradicting Mendel's essential results.

Determiners compared with chemical atoms, but seen to be vastly more complex

8. Not only are the determiners inherited as units, but they ordinarily remain unmodified, whether they produce any visible features or not. We are reminded of the phenomena of chemistry. Thus oxygen and hydrogen, two gases, when united become water, which is not at all like either of them. An atom of oxygen may today be part of water, tomorrow part of iron rust, and the third day again appear as oxygen, not in the least changed by the temporary loss of its ordinary properties. It is quite certain that the determiners are not chemical atoms, they are doubtless thousands of times more complex than that; nor do they form chemical combinations as do the atoms, but they resemble them in their stability and reappearance after having seemed to cease to exist.

Homozygous or pure-bred and heterozygous or cross-bred individuals

9. Having thus postulated the existence of independently inherited determiners, pairs of which are mutually exclusive, we can proceed to develop a theory of Mendelian inheritance. Each plant (or animal) is double or duplex, in the sense that it inherits or receives one set of determiners from each parent. Should the two sets be alike, we say that the individual is pure-bred, technically *homozygous;* should they be different, it is cross-bred, or *heterozygous*. We may express the facts by formulæ, as did Mendel, in which, however, we cite only the characters with which we are immediately concerned. Let a pure-bred tall pea (TT) be crossed

with a pure-bred short or dwarf pea (*tt*), the offspring will be tall, but *will have inherited determiners for both characters*. Its formula will be *Tt*. Of course the formula for the whole plant (something no one has yet tried to construct) would be excessively long and complex, but we confine ourselves to one or a few pairs of characters. We are in the position of a man who might be looking at a crowd. He could not follow the movements of all the individuals at once, but he could select any one or two individuals and see exactly where they went and what they did.

Only half of the determiners passed to the offspring

10. Now it appears that while each individual has two sets of determiners, he can give to his progeny only *one* of these; otherwise the number would be double in each generation. So the cross $TT \times tt$ (we use $\times$ to signify crossing) gives us *Tt*, and can give nothing else, because each parent contributes *one* item, and the one has only *T* to give, the other only *t*.

The *Tt* plant is tall, because tallness is *dominant* and dwarfness is *recessive*.

So-called laws of chance in inheritance

11. Suppose we take the F_1 individuals, which are, as we have said, *Tt*, are cross-bred or heterozygous, and cross them together, thus: $Tt \times Tt$. Each parent can now give *T or t*, and gives either quite without choice or discrimination — as we say, "at random." Let us follow the fortunes of the first *Tt*. Of this pair, the *T* goes out, and is equally likely to meet *T* or *t* from the other parent. Thus half such *T*'s will form the combination of *TT*, and the other half *Tt*. Now the *t* of the first parent goes out in the same way, and is also equally likely to meet *T* or *t*, and in half the cases forms *tT*, in the other half *tt*. We thus get the four possible combinations, all equally likely; they are *TT*, *Tt*, *tT*, and *tt*. This sounds confusing, but the same result may

be reached experimentally, without going to the trouble of raising plants. Take a half-dollar and toss "heads or tails." On the first toss you are equally likely to get heads or tails; so also on the second toss, the first having no effect on the second. So half the first tosses of each pair will be heads (H) and half will be tails (h). Now, after tossing heads, half the second tosses (on the average) will be heads and half tails. The same after tossing tails. Hence, after a large number of successive pairs of tosses, you get this result, $\frac{1}{4}HH$, $\frac{1}{4}Hh$, $\frac{1}{4}hH$, $\frac{1}{4}hh$. The tosses, like the Mendelian combinations of determiners, follow the "laws of chance." In a small number of cases the proportions will not be likely to agree exactly with the theory, but the larger your statistics, the closer the agreement.

Explanation of the three-to-one ratio

12. Returning now to the visible results, the F_2 generation from our cross between the tall and dwarf peas gives us $\frac{1}{4}TT$, $\frac{1}{4}Tt$, $\frac{1}{4}tT$, $\frac{1}{4}tt$. The first is homozygous or pure-bred for tallness, and will of course be tall. Crossed with others like itself, it will give only talls — provided that by "like" we mean not merely in appearance, but in actual constitution. Tt and tT differ only in that one got its tall factor from one parent, the other from the other. As this makes no difference, and as T is dominant, both will be tall. Finally, tt is homozygous for dwarfness, the recessive character, and will therefore be dwarf. It is what we call an "extracted recessive," and when crossed with others like itself can give only dwarfs, in spite of the fact that both its parents and one of its grandparents were tall. We now see how the three-to-one ratio is explained theoretically; given the facts, it seems very simple, but it is hard to exaggerate the credit due to Mendel for first detecting the law governing inheritance.

Mendel's work published but ignored

13. Mendel's work was duly published, in a paper which is a model of clearness and convincing logic. Nevertheless, it was completely ignored. The botanist Nägeli, with whom he corresponded, was unable to appreciate the importance of his novel ideas. The Brünn society sent out its publications to other societies and to libraries, but no one understandingly read Mendel's account. Darwin, who of all men was most fitted to make good use of it, never saw it at all. Mendel was appointed Prälat, and took upon himself important executive duties. In 1872 the government imposed special taxes on the property of religious houses, and Mendel, claiming that all should be equal in law, resisted this injustice. The latter part of his life was spent in the bitter struggle for what he considered to be the right, and he died a disappointed man, on January 6, 1884. A few years after his death the tax he had resisted was removed without debate. As to his scientific work, he died wholly unknown, though it is related that he used to say hopefully, "*Meine Zeit wird schon kommen!*" (My time will surely come!)

Rediscovery of Mendel's papers and the rise of Mendelism

14. It did come, indeed, but not until 1900, sixteen years after he had gone. Three naturalists, De Vries, Correns, and Tschermak, at about the same time, rediscovered Mendel's paper and perceived its significance. Professor Bateson, at the University of Cambridge, in England, took up "Mendelism" with extraordinary vigor, and became the leading exponent of the subject. In many places experiments were begun, to test the theory. It was soon found that Mendel's principles were applicable not only to plants, but also to animals, including man himself. Numerous exceptions and difficulties were encountered, but these served only to bring to light new facts which were

eventually, in one way or another, accommodated by the rapidly extending theoretical structure. "Mendelism," as we know it today, would astonish Mendel himself, but his researches stand at the very root of the growth which has sprung from the work of modern experimenters. Most wonderful of all, perhaps, is the confirmation and extension of the theory made possible by investigations into the minute structure of the germ cells, due to instruments and methods wholly out of Mendel's range, belonging to a science called cytology, which scarcely existed in his time.

CHAPTER EIGHT

THE RED SUNFLOWER

1. THE red sunflower may be studied in illustration of the principles of heredity and of plant breeding. Its advantages for this purpose arise from the fact that its origin is known, and its whole history belongs to recent times, since the rediscovery of Mendel's law. It is also very easily grown, and the various crosses may be made with little difficulty. It is only necessary to cover the heads with paper bags before they come into flower, and at intervals dust the stigmas with pollen from another plant. The great amount of pollen produced by the flower head, although reaching its own stigmas, has no effect. The plants are always, with possible rare exceptions, sterile with their own pollen. When the summer is over and the seed is ripe, the heads may be cut off, bags and all, and the seed garnered at leisure.

Mendelian phenomena illustrated by the red sunflower

2. The sunflowers (*Helianthus*, which in Greek means sunflower) are peculiar to the Western Hemisphere. They are most numerous in the United States east of the Rocky Mountains, but extend south to the Andean region of South America. The common garden sunflower (*Helianthus annuus*) is an annual, coming from seed every year. Others are perennial, growing year after year from the same clump; while still others send out underground branches, from which new plants arise, the original roots and stems perishing at the end of the season. All these plants are *herbaceous;* that is, the stems die at the end of summer or fall.

Characters of sunflowers

Sunflowers belong to the great group of plants called *Compositæ.* The so-called flower is really a *flower head*, consisting of a disklike or more or less elevated

receptacle, on which are placed the very numerous flowers or *florets*. The outer florets bear the large rays, which give the head its conspicuous appearance. These are sterile and do not produce seed, but they make the sunflowers easily visible to the bees, which carry the pollen and so bring about fertilization. The large center or disk is composed of great numbers of small florets, each giving rise to one seed. The florets do not all bloom simultaneously, and a brief examination will often show that a head which is apparently in full flower is really mainly still in bud.

Varieties of common sunflower

3. The garden or annual sunflower, aside from variations in color, has several distinct forms. That with the tall single stalk and the enormous head at the summit is commonly known as the "Russian sunflower." The disk may be a foot across. This variety forms an important crop in Russia, but it did not originate there, and the name is as misleading as that of the "Irish potato," which also is of American origin. The first description of the large-headed sunflower was published in 1567, and was made from plants growing at Madrid, in Spain. Its native country was supposed to be Peru, but more probably it was Mexico, as no similar sunflower is known to exist in Peru. The wonderful symmetrical heads, with their bright orange rays, early attracted the attention of artists. Anton Van Dyck or Vandyke (1599–1641), when painting his own portrait, introduced a sunflower into the picture, — a very large head, with two or three rows of rays. In the nineteenth century Edward Burne-Jones, the English painter, wrote: "Did you ever draw a sunflower? It is a whole school of drawing and an education in itself. Do you know what faces they have, — how they peep and peer, and look arch and winning, or bold and a little

insolent sometimes? Have you ever noticed their back hair, how beautifully curled it is?"

The prairie sunflower

4. In Western North America, in that great prairie region which old geography books used to describe as the "Great American Desert," the sunflower grows wild. It is not like the large-headed garden kind, for it has many branches and much smaller heads. Some botanists call it a distinct species, but it is perfectly fertile when crossed with the "Russian" variety, and when examined in detail, presents no material difference in the structure of its parts. These wild sunflowers were brought into cultivation by the American Indians in very early times, from Canada to Mexico. They yielded an abundance of oil, "which the Indians, more mindful of their appearance than of their diet, mostly used for anointing their hair and skin." The seeds were parched and ground and made into bread. The state of Kansas, recognizing the sunflower as one of its most characteristic products, long serviceable to man, adopted it as its emblem.

Coloring matter of sunflowers

5. The coloring matters in the sunflower are obviously of more than one kind. Aside from the *chlorophyll*, to which the green of the leaves and stems is due, there is the orange or yellow pigment in the rays. This, as well as the chlorophyll, can be seen under the microscope to be located in definite particles. A closer inspection usually shows some purplish speckling on the stem, and the prairie sunflower has a dark disk. The dark color of the disk florets, as well as the speckling on the stem, is caused by a coloring matter called *anthocyanin*, dissolved in the cell sap. Anthocyanin (from Greek words meaning flower-blue) is a name for a class of pigments which may be pink or blue, and when extracted may often be changed from one color to the

other by chemicals. The acid state is pink, but when an alkali is introduced the solution may become blue. The anthocyanin of the sunflower turns green in alkali, but this is probably due to the presence of a yellow substance (flavone).

Red sunflower due to an extension of anthocyanin already present

6. The first sunflower with red (maroon) on the rays seems to have been observed in South Dakota in 1892, but no record was made of the fact at the time. In 1910, in Boulder, Colorado, a plant was found by the roadside, having the rays strongly suffused with chestnut red. This was an example of the prairie species or race, and had not come from a cultivated source.

FIG. 11. The red sunflower (*Helianthus annuus*, variety).

The red color was the same anthocyanin as occurs in the disk of these sunflowers, only greatly increased in amount and extending over the rays. The coloring matter was really pink, but the effect on an orange background was chestnut. It was an astonishing thing to see a style of coloration entirely new to *Helianthus*, though well known in some allied plants, and due not to any new substance, but to an increase of one common in sunflowers. Thus does Nature produce novelties, by taking advantage of what exists. Man, noting the process, may in certain respects follow her example. If he cannot produce variations, he can at least often combine them, and the combinations will be in every practical sense new forms.

Red sunflower found at Boulder, Colorado

7. The Boulder variety with reddened rays existed in 1910 as a single plant. Since sunflowers are sterile with their own pollen, it could be propagated only by crossing with orange-rayed forms. Would the red appear in the offspring, would it be dominant or recessive? When the following summer came, and a garden full of sunflowers burst into bloom, about half showed the red color. It is probable that this may be explained as follows: The original plant was of course the result of the combination of two *gametes* or germ cells, derived from its parents. The change in the germ plasm which gave rise to the red variety probably took place during the formation of one of these gametes. Thus, although there may have been no "red" parent, the plant was a cross between a "red" and a "no-red" gamete. These diverse gametes united to form a *zygote*, or fertilized cell, from which a plant developed. Red being dominant, the result was red; but the plant would produce two kinds of gametes, "red" and "no-red." In the new crosses, the other parent was always orange-

rayed (no-red); so "red" × "no-red" would give "red," and "no-red" × "no-red" would give orange rays. If we use R for "red" and r for "no-red," the formula is as follows:

$$Rr \times rr = Rr \text{ and } rr \text{ (half of each)}$$

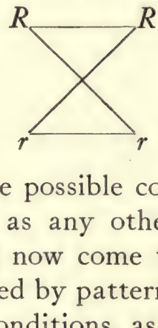
Of course the actual crosses are between the gametes, and are to be expressed thus:

$$R \times r = Rr$$
$$r \times r = rr$$

Development of a pure-bred strain

8. Having now obtained a number of plants like the original one, these could be crossed together, and would give *homozygous* or pure-bred reds.

Thus $Rr \times Rr$ will give RR, Rr, rR, rr, a quarter of each being the theoretical expectation. The gametes, being R and r (in equal numbers) on each side, and combining at random, give this result as follows:



The lines indicate the possible combinations, each one as likely to happen as any other. The homozygous reds, if isolated, will now come true, except so far as they may be influenced by pattern and dilution factors, and environmental conditions, as explained below.

Production of wine-red sunflower. The 9, 3, 3, 1 ratio

9. There had been known in cultivation since 1889 a variety of the garden sunflower called "primrose," having the rays pale yellow, the color of the English primrose. This had arisen as a "sport" from the ordinary kind, and the same variation has since been observed in the prairie sunflower. Knowing that the red of the red sunflower was chestnut only because on an

orange background, it was naturally suggested that if the color could be put on the "primrose" rays, an entirely new effect would be the result. How might this be done? Homozygous (pure-bred) red was crossed with primrose, and to save a year the progeny were grown in the greenhouse during the winter. They were very ordinary heterozygous reds. The cross had been as follows, using *O* for orange and *o* for primrose (no-orange), *R* for red and *r* for no-red :

$$RROO \times rroo = RrOo \text{ (gametes } RO \times ro \text{ give } RrOo \text{ zygote)}$$

RROO is the same as *RR* given above. So long as all the plants had the orange background, it was not necessary to insert it in the formula.[a] The *RrOo* plants are red on orange, because red is dominant over no-red, and orange over no-orange (primrose). In former times breeders had sometimes made first crosses as just described, and failing to get the desired result had neglected to continue the work. Thanks to Mendel, it was possible to see ahead in this case. The apparently ordinary reds had one property which no reds had ever had before, they were heterozygous for orange. It was only necessary to cross them together. In this cross the "red" factors and the "orange" ones combined independently of each other. The reds, as explained above, gave *RR*, *Rr*, *rR*, and *rr*, which is three reds to one plain orange. The orange, on the same principle, gave *OO*, *Oo*, *oO*, and *oo*, which is three orange to one primrose. But as these combinations were independent, each one was as likely to occur with one as another of the other group. The theoretical expectation, following the so-called law of chance, is that *RR*, for example, in each four times will happen to occur once with *OO*,

Oo, *oO*, and *oo*. The total result may be expressed by a diagram, as follows, in which each zygote is represented within a square. Each combination of red and orange is repeated four times, combining with the other four. The red series is repeated vertically, the orange transversely.

RR *OO*	*Rr* *OO*	*rR* *OO*	*rr* *OO*
RR *Oo*	*Rr* *Oo*	*rR* *Oo*	*rr* *Oo*
RR *oO*	*Rr* *oO*	*rR* *oO*	*rr* *oO*
RR *oo*	*Rr* *oo*	*rR* *oo*	*rr* *oo*

It will be seen that, of the sixteen squares, nine have at least one *R* and one *O*, and therefore will be red on orange, or chestnut red. Three have *O*, but no *R*, and are plain orange, like the wild ancestor. One has neither *R* nor *O*, and so is primrose. Finally, three have *R* but no *O*, and are red on a primrose background. It is these last we aimed to get, and as was expected, they present quite a new shade of color. The red is wine-red or "old rose." Thus a new color variety is "created," by recombining old factors. In the original experiment giving this result the plants obtained were 71 chestnut-red, 19 orange, 25 wine-red, and 8 primrose. The theoretical expectation, following the 9, 3, 3, 1 ratio, was 69 chestnut, 23 orange, 23 wine-red, and 8 primrose.

Color patterns in sunflowers

10. So far, we have considered only the shade of color. It was surprising to find that, given a certain color, it might appear in various different patterns.

These patterns are the same for the chestnut as for the wine-red. The rays may be entirely red, or the ends may be yellow or orange. Sometimes the red is confined to the middle of the ray, and the whole effect is that of a red ring on an orange ground. These patterns are inherited *independently of the color*, so that a flower may have the pattern factor, yet no development of anthocyanin to make it manifest. It is a remarkable fact that photography will reveal the patterns in apparently uniform rays, showing that there is already something there, not readily appreciated by our eyes. The patterns of another species of sunflower, *Helianthus cucumerifolius*, are quite different from those of the *H. annuus*.

11. The combinations of color and pattern give quite a variety of forms, but there are in addition many variations in structure. Some of these are horticulturally worthless, though scientifically interesting — such as the variety *tortuosus*, with the ends of the rays twisted as though in curl papers. There are so-called doubles, in which all the florets are ligulate or rayed. The rays may be in two or three rows, an approach to the type of the star dahlias. Some forms have the rays cleft at the end. Perhaps the most interesting recent development is the collarette, in which the rays have a narrow, more or less curled lobe attached near the base, after the manner of the well-known collarette dahlia. These modifications affect the flowers, but they may be combined with various growth forms, and hybrids are possible between different species — even between annuals and perennials. It will thus be evident that the possibilities are so numerous that we can have no idea at present of their limits. What the dahlia has done, in its horticultural history of about a century, the sun- **Various sunflower varieties**

flower may in some measure parallel. There is, however, this important difference: the dahlia can be propagated vegetatively, by tubers, and hence it is possible to preserve and increase the various heterozygous forms. The sunflower, propagated by seed, will not remain constant unless homozygous; and then, under ordinary circumstances, it must be hand-pollinated. Consequently, it will be practically impossible to maintain a large number of pure strains representing the variations of the sunflower. Some of the best semi-doubles appear to be necessarily heterozygous, and consequently incapable of producing seed that will regularly come true.

Variation in expression

12. Finally, it must be added that even when the color and marking factors are those desired, there may be great variations in "expression." These may in some cases be caused by the presence of what are called "dilution factors," having the property of causing the color to be relatively faint, or diluted. Such factors have been demonstrated even in animals. They may be due also to purely environmental causes, having nothing to do with heredity. For example, it appears that the red tends to fade out in very hot weather, and it has been claimed that its appearance is greatly affected by the soil.

Plant breeding as an occupation

13. Plant breeding, in the light of our present knowledge, is a fascinating subject, and may be carried on very well in a small garden. It is especially suitable for amateurs, who do not expect to earn their living in this manner. They can experiment as they will, without being obliged to consider financial results. The best way is to select some species or genus of plants, and study it intensively, becoming acquainted with all its known variations and special peculiarities of struc-

ture and habit. It is desirable to consider the character of the plant from the standpoint of a breeder; thus it should be one which will do well in the locality, which will not take too long to come to maturity, which can be crossed without undue difficulty. Some of the more difficult and lengthy problems are equally worth while, but they must be solved by institutions, which are not limited to the short span of a human life.

CHAPTER NINE

THE CHROMOSOMES

Cytoplasm and nucleus

1. The *cytoplasm* or substance of the cell incloses a relatively small body known as the *nucleus*. In some cases there is more than one nucleus, and in certain special kinds of cells, as the red corpuscles of the blood, the bacteria, and very few Protozoa, no nucleus appears. When the nucleus is absent, it is possible, at least in some cases, that the nuclear matter (*nucleoplasm*) is diffused through the cell. Ordinarily the nucleus is a small, rounded body near the center of the cell, which is much more deeply colored with certain stains than the cytoplasm, so that microscopic preparations of animal tissues often appear to be minutely speckled. The spermatozoön, or sperm cell, the contribution of the male to the process of fertilization, carries very little cytoplasm. Being motile, having to seek the egg cell, it cannot afford to be burdened with anything not necessary for its peculiar function. The nuclear matter is present, and can be shown to consist of materials similar to those in the relatively gigantic egg cell.

Chromatin and chromosomes

2. From its universal presence in ordinary cells, and the fact that a piece of cytoplasm cut from a cell, if containing no nucleus, dies, we assume that the nucleus is of special importance for life. On examining more closely, we find a kind of material in the nucleus which stains most readily, known as *chromatin*. This chromatin, when cells are dividing, is seen to collect in small bodies, usually more or less rod-like or thread-like, known as *chromosomes*. The words "chromatin" and "chromosome" imply the presence of color, and are misleading, since the material is colored only when artificially stained.

3. On examining these chromosomes, we note the fact that for any particular kind of animal or plant **The chromosomes definite in number**

Drawing by C. E. Allen

FIG. 12. Chromosomes in cell of lily (*Lilium canadense*), greatly magnified.

there is a definite number in each cell. The two exceptions to this general statement do not invalidate the rule, but when explained are seen to be quite in harmony with it. One is, that the number may be slightly different in the two sexes; the other, that the *gametes*, or cells uniting in the process of fertilization, contain only half the number characteristic of the species.[1] The number of chromosomes in different organisms differs greatly; thus the cells of a certain parasitic worm have

[1] Other exceptions recently noted do not invalidate the general principle. Miss Caroline M. Holt has found that the cells in the intestine of the pupa of the mosquito may contain many more chromosomes than are normal for the species, but the numbers are always multiples of three. The chromosomes have increased by division without the usual accompaniment of cell division. Such cells degenerate or disintegrate, and are absorbed as nutriment by the cells of the developing adult. (*Journal of Morphology*, September, 1917.)

only two, while other animals and plants have very many. So regularly is any difference in the number of chromosomes associated with a difference of species, that naturalists have come to regard it as a *specific character*. Thus Professor E. B. Wilson was examining the chromosomes of certain bugs (*Hemiptera*) which a specialist in entomology had declared to be all of one species. He discovered that he had two lots, from different parts of the country, differing in the number of chromosomes. He then returned some of them to the specialist, who was able to find valid external characters in the insects, and was obliged to confess that he had been mistaken; that there really were two species.

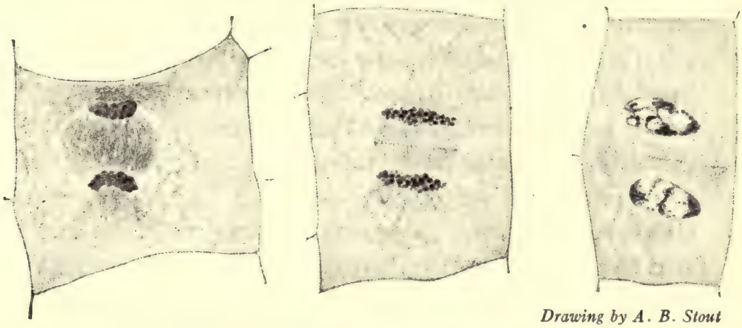
Mutations with altered numbers of chromosomes

There are cases, however, in which differences in the chromosome number have arisen under observation, and do not separate what we should ordinarily call species. Lamarck's evening primrose has 14 chromosomes; but from it has arisen a large form, called by De Vries *Œnothera gigas*, which has 28 chromosomes. Another, called *semigigas*, has 21. These plants, which De Vries calls mutations, have very distinct external characteristics accompanying the difference in chromosomes. If we found them on different islands or in different countries, knowing nothing of their history, we should doubtless call them "good species," and should point to the chromosome count in confirmation of our opinion.

Maturation of germ cells; the reduction division

4. The behavior of the chromosomes in the germ cells or fertilizing cells is remarkable, and confirms the view that they are of particular significance for heredity. The germ-cell material is in most cases set aside early in development, and is compelled to wait until sexual maturity for its opportunity. It does not become specialized, in the manner of muscle cells or nerve cells, as by so doing it would lose the power of contributing

to the development of a new individual. It merely increases in quantity by the absorption and assimilation



Drawing by A. B. Stout

FIG. 13. Cells of sedge (*Carex aquatilis*), greatly magnified. Stages of cell division (mitosis), an equal amount of chromatin going into each of the two cells.

of food, while the number of cells is increased by division. When the proper time comes, the germ cells go through a peculiar process known as *maturation*, whereby they are made ready for *fertilization*, and the consequent origin of new individuals. In ordinary cell division (called *mitosis*) the chromosomes divide, so that each resulting cell gets half, and has the same number of chromosomes as the mother cell. In the maturation divisions something different occurs. The sperm cells are formed by a division in which half the chromosomes go into one cell, half into another. There is no division of the individual chromosomes, such as occurs in mitosis. When there is an odd chromosome, one of each pair of sperm cells has it, the other is without it. The maturing egg cell, on the other hand, finally throws off a minute particle known as a polar body. This is formed by a division of the nucleus, in which half the chromosomes remain, while the other half pass into the polar body. Thus the egg cell, too, comes to have only half

the specific number of chromosomes at fertilization. The polar bodies perish, and consequently some of the material of inheritance is wasted, but the surviving group of chromosomes carries all the cytoplasm necessary for the beginnings of development after fertilization. Were this cytoplasm divided equally, in a process similar to that which makes two sperm cells, there would probably not be enough for either, and both, though fertilized, would perish.

The *spermatocyte*, or sperm-forming cell, divides to form two, and these divide again to form two spermatozoa each. The *oöcyte*, or egg-forming cell, does not thus divide; but its nucleus divides, so that there results one large cell and a polar body. The large cell undergoes another nuclear division, as described above, when the second polar body is formed and the number of chromosomes is reduced to half. The first polar body also divides, but comes to nothing. Thus, where four spermatozoa are formed, the corresponding cells of the female are one functional egg cell and three minute cells which perish. As a matter of fact the spermatozoa produced by the male are vastly more than four to one egg cell of the female, following the law that the number produced must vary with the chances of survival. The male produces myriads of spermatocytes, and hence vast numbers of spermatozoa.

When fertilization takes place, each *gamete* (matured germ cell) brings to the union its half set of chromosomes, and thus the regular number is made up again. Were it not for this, the number would be altered at each fertilization; thus, without the *reduction division*, each gamete would carry the full number typical of the species, and uniting, the two would double the number. After several generations there would be an enormous

number of chromosomes in every cell. The resulting mechanism would no longer be able to develop normally, if at all.

The whole process may be represented by the following diagram, in which A, A', and again B, B', are homologous chromosomes, derived from different parents and representing similar structures, but not precisely alike. At the reduction division, because one of each pair goes out, we get gametes of four sorts, AB, $A'B$, AB', $A'B'$. If these are sperms, uniting with a similar series of eggs, we may have:

Sperm		*Egg*		*Zygote*
AB	—	$A'B'$	=	$AA'BB'$
$A'B$	—	AB'	=	$A'ABB'$
AB'	—	$A'B$	=	$AA'BB'$
$A'B'$	—	AB	=	$A'AB'B$
$A'B'$	—	$A'B'$	=	$A'A'B'B'$

The first four zygotes are all alike, and are *heterozygous* (cross-bred) for both sets of factors carried by the chromosomes; the fifth is unlike the others, being *homozygous* (pure-bred) for both sets of factors; but if dominance is complete, it will *appear* like them.

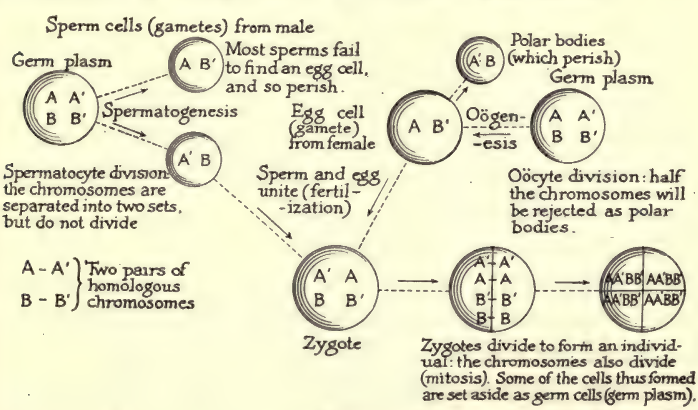


FIG. 14. *Drawing by W. H. Schanck*

Reduction and fertilization in the higher flowering plants

5. In the higher plants there is a peculiar complication whereby certain cells come to have *more* chromosomes than the number normal for the species. The pollen tube, which has developed from the pollen grain, brings to the ovary two sperm cells, one of which unites with an egg nucleus which has the reduced number of chromosomes. The duplex number is thus made up, and so far the process is essentially like that observed among animals. In the maturation of the egg nuclei, division takes place as in animals, and part of the chromosomes are rejected. Two of the particles come together and produce a nucleus in which, apparently, the full number of chromosomes is restored. This is then fertilized by the second sperm nucleus, and the resulting zygote has one and a half times the duplex number of chromosomes. Thus if 4 is the simplex number and 8 is the duplex, then it will have 12. The zygote so formed does not produce an embryo, but instead produces a quantity of undifferentiated cells, constituting the *endosperm*. This endosperm serves as nourishment for the embryo proper, or the plant into which it develops. That there is a real process of fertilization in the formation of the endosperm is proved by the phenomenon called *xenia*, whereby the seeds show the influence of the pollen parent. This is especially noticeable in corn (maize), where red grains appear on white ears, when they have been fertilized by pollen from plants carrying the factor for red.

The above account is based on recent observations on particular plants; it is probable that it is essentially true for all the higher flowering plants (angiosperms), but there are doubtless differences in detail.

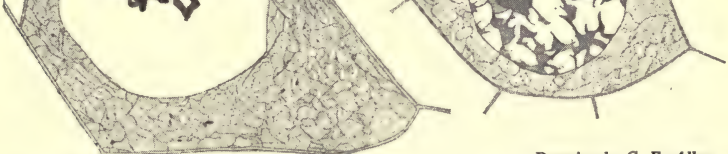
6. The chromosomes are not all alike. They may differ visibly in size or shape, but there are many

reasons for believing that their differences are much more profound than mere inspection would suggest. At fertilization a set from each parent goes to the formation of the zygote, and (excepting the odd chromosome, to be considered later in connection with sex) the two sets correspond in the sense that each type of chromosome has its mate. Thus the cells of the individual are duplex or double, containing a contribution from each parent. Shortly before the reduction division, the corresponding chromosomes, derived from the parents of the reproducing individual, are seen to become coupled, the pairs uniting side by side or twisting more or less around one another. This phenomenon is called *synapsis*. There is reason for thinking that when they separate, they do not always retain their original integrity, that there may be some interchange of materials. This matter has been investigated by Dr. T. H. Morgan and his associates at Columbia University, with very remarkable results. In the study of inheritance in flies of the genus *Drosophila*, it was found that certain characters were not inherited in accordance with the theory of random sampling, but came out in groups. At first

One set of chromosomes from each parent

Synapsis

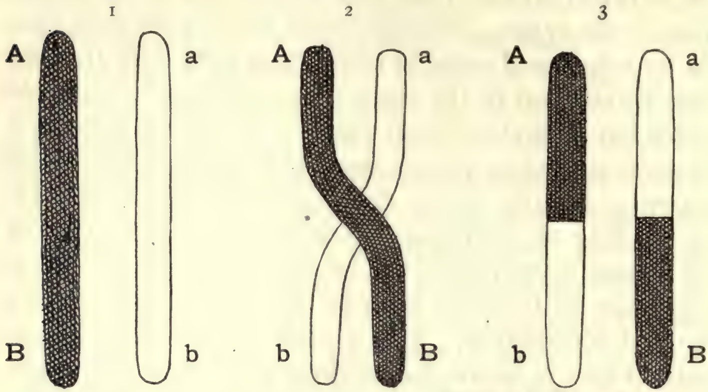
Linkage, and its results



Drawing by C. E. Allen

FIG. 15. Cells of lily (*Lilium canadense*). 1, synapsis; 2, resting stage. Greatly magnified.

it might well seem that this could be explained on the supposition that each group of characters was due to a



Drawing by R. Weber (after Morgan)

FIG. 16. Linkage and crossing-over. *A, B,* determiners in the same chromosome, are linked. But at synapsis (2) the chromosomes divide, and the upper half of each becomes attached to the lower half of the other (3). Then *A* and *b* will go together, no longer *A* and *B*. The division may occur at any point, or at more than one point, but the nearer the determiners are together, the less likely are they to be separated.

single inherited factor, which gave rise to various results. This, however, was negatived by the fact that the characters were not necessarily associated, but only generally so. It gradually became evident that the phenomenon, known as *linkage*, had to do, not with the identity of the factors, but with their occurrence in the same chromosome. This was confirmed by the discovery that the number of such groups in *Drosophila* corresponded with the number of chromosomes. Should this theory be true, how might we account for the fact that linkage is not absolute, that there are exceptions? Indeed, not only are there exceptions, but they evidently follow some rule, certain of them being much more frequent than others. The idea was suggested that per-

haps failures of linkage might be due to the fact that in synapsis there was an exchange of material between the homologous chromosomes, that synapsis was in fact a sort of "shuffle and cut" process. Should this be true, it might be expected that if the factors or determiners occupied definite places in the chromosome, those nearest together would be least likely to be separated. This hypothesis was tested by the most elaborate breeding experiments, and eventually the relative positions in the chromosomes of many factors were determined. The results not only agreed with the hypothesis, but served to confirm it. Thus if the relative positions of *A* and *B* were calculated, and then those of *B* and *C*, it followed that *A* and *C* ought to behave in a certain way when brought together in a cross, and predictions of this sort were fulfilled in numerous instances. It was found that some factors crossed over less than once in a hundred times; others as often as once in every other time. In the latter cases the factors lie far apart, probably near the opposite ends of the chromosome. Very recently Mr. C. B. Bridges has been able to show that in a particular case, instead of an exchange of substance, a piece out of a chromosome was lost. In an experiment with *Drosophila* flies, a particular character which should have appeared, according to the known characters of the ancestors, failed to develop. It occurred to Bridges that if it, or rather the determiner for it, had really got lost, very possibly other determiners, known to lie very close to it in the chromosome, had also gone. He tested this by further breeding, and found it to be the case. Thus he at once confirmed his idea concerning the loss of a fragment, and furnished additional proof of the theory concerning the position of the determiners in the chromosome.

Loss of part of a chromosome

Synapsis leads to variability

What is the purpose of the synaptic shuffle and its resulting phenomenon, the crossing over of factors otherwise linked? Evidently, in heterozygous or cross-bred races, it increases variability, and provides for the almost endless variety of living types, furnishing the material for natural selection. Through such means Nature furnishes, as it were, innumerable keys to unlock the doors of opportunity. Many, indeed most, must fail; but many succeed, and these fill the world with variously adapted forms of life.

CHAPTER TEN

FERTILIZATION

1. REPRODUCTION comes about through division. In the simplest forms of life the cell is the individual, and it divides into two equal parts, each of which feeds and grows to the size of the original cell. In the many-celled animals and plants, — that is, all the higher forms, — cell division does not usually give rise to new individuals. As in the first case, new cells are produced, but they are retained as part of the body of the creature. Sometimes, however, a mass of these cells is set apart, forming a bud or similar structure, which may break away and become a separate individual. Thus the *Hydra*, a small cœlenterate animal found in ponds, produces buds which develop into what seem to be little hydras parasitic on the mother. These presently break away, and become new individuals. Many plants reproduce by runners or tubers; in some kinds of sunflowers the original plant dies, while its underground branches produce new plants the following year. In Arizona certain branching cacti rarely produce seed, but their branches break off and take root where they fall, thus producing new plants.

Reproduction through division

2. In all the cases just cited there is no fertilization, in the biological sense. It is found, however, that even among the one-celled animals (*Protozoa*) *conjugation* frequently takes place, though apparently not essential. This conjugation consists in the union of two individuals; in Paramecium these come together, exchange portions of their protoplasm, and then separate. Each may be said to have fertilized the other, by giving it a portion of its substance; neither has lost in bulk, since the exchange is equal. In other cases, as for instance

Conjugation in lower forms of life

certain seaweeds, multitudes of minute cells are thrown out, all exactly alike. These join in couples and completely fuse, after which they develop into new plants. This union is also fertilization, and unlike the Paramecium, the cells participating will not develop or continue their race without it.

Fertilization by union of a sperm cell with an egg cell

3. In the higher forms of life, the cells which take part in fertilization are not alike. The sperm cell produced by the male is very different in appearance from the egg cell produced by the female, although each contains the essential contribution of chromosomes. Fertilization is no longer optional, as it were; it is obligatory. In the highest plants, indeed, certain vegetative methods of reproduction are still possible; and when impossible under natural conditions, they may still take place through man's influence, by cuttings or grafts. Nevertheless, the seeds will not develop without some stimulus, something of the nature of fertilization. In the higher animals reproduction by the union of sperm and egg cells is the invariable method, and we think of fertilization as necessary for the continuance of life.

Parthenogenesis, or reproduction from unfertilized egg cells

4. We think of the process of fertilization as consisting essentially of the union of the protoplasm of two cells derived from different individuals. These cells, called *gametes*, have the simplex or reduced number of chromosomes; they make up the full number when united to form the zygote. This seems clear enough, but we are puzzled when we find that in many animals, even such highly organized ones as insects, *parthenogenesis* takes place; that is, reproduction from unfertilized egg cells. This is not like the simple division of the protozoan, or the vegetative propagation of the plant; here we have an egg cell, apparently made for fertilization, and it develops without it! It is, as it

were, self-fertilized. Many egg cells which thus develop without fertilization do not lose half their chromosomes, and thus the cells of the resulting individual carry the full number, notwithstanding the lack of any contribution from a sperm.

Artificial parthenogenesis, caused by chemical or physical stimuli

5. Still more surprising, however, is the fact that Dr. Jacques Loeb has been able in a number of cases to bring about *artificial parthenogenesis.* This means that he has succeeded in causing development in unfertilized eggs through the action of various chemicals, or even by mechanical or physical stimuli. In all such cases, of course, there is no possibility of the union of protoplasm from different individuals. It begins to appear, then, that if we mean by fertilization that which induces growth, the protoplasmic union has little to do with it.

Development caused by the sperm of unrelated animals

6. Dr. Loeb also found that development may often be made to occur by introducing the sperm of some quite different animal; for example, sperm of a sea urchin added to eggs of a starfish. The resulting organisms would develop properly, but would show *only maternal characters.* That is, they would possess none of the characters of the male parent, the sperm of which had "fertilized" them. Evidently, then, even here there had been no intimate protoplasmic union.

Cross-fertilization, the union of cells with diverse powers

7. The final conclusion is, that the egg cell contains within itself all the essential factors for development. Since, however, bisexual reproduction has come to be the normal method among the higher animals and plants, typical egg cells develop qualities which cause them to remain latent until a sperm arrives. It is like the sleeping beauty in the old story, waiting to be awakened by the right prince. In parthenogenesis she awakes of her own accord, or in response to some untoward disturbance. In a sense, there is less of magic

in this than in the more common event. As so often happens when we study life, we find that it is the commonplace, the everyday thing, which is most marvelous. So careful is Nature, in the majority of cases, to bring about cross-fertilization, to unite diverse individuals in the stream of inheritance, that innumerable adaptations have arisen to that end. Thus many flowers, although producing both ovules and pollen, do not ripen both at the same time, or have special structures to bring about cross-fertilization through the agency of insects. In the common garden sunflower, although the pollen of any head falls all over the adjacent stigmas, it is quite inert, and no seeds are produced unless pollen is brought from another plant.

Fertilization a double process

8. From Dr. Loeb's experiments with the sperm of unrelated animals we gather this, that what we ordinarily call fertilization is a double process. It is, first of all, the initiation or liberation of the activities of the egg cell, and secondly the union of the nuclei with their chromosomes. The latter has to do with heredity, the former not at all. The wrong kind of sperm may serve as a fertilizer in the sense of starting development, because the chemical substances it carries are adequate for that purpose; but its chromosomes are too different from those of the egg cell to unite with them to make an organism. Many different machines may be run by the same power, but the parts of those machines cannot be mixed up and transposed without stopping all production.

CHAPTER ELEVEN

SEX

1. Nearly all familiar animals are *bisexual;* that is to say, they have two sexes, male and female. The sexes may be so similar in appearance that they cannot be distinguished without close examination; or they may be so different that it is hard to find any characters in common. Among the lowest animals we cannot distinguish sexes; all the individuals are substantially alike, and if they conjugate, it may be impossible to regard one or the other as male or female. Sometimes there is a difference in size, and then the smaller cell is thought of as male, the larger as female; but this is only a rather loose analogy. Among the higher plants we have no trouble in recognizing sex, though the sex phenomena are in many respects quite unlike those of animals. An ordinary flower, such as a buttercup or a rose, has stamens and pistils. At the top of each stamen is an anther, and when this bursts at maturity, the yellow powdery pollen is set free. This pollen consists of grains, which are not gametes or germ cells, but which produce such. At the bases of the pistils are the ovules, and these again are not germ cells, but are the producers of them. The pollen, falling on the pistil, grows a pollen tube, which conveys the gametes to the ovule, to meet the gametes there developed, and fertilization takes place. Such flowers are neither male nor female, but they produce structures which take on true sexual functions.

The two sexes

Sex of plants

In many cases the stamens and pistils do not occur together in the same flower. They may be borne by different plants, which, as in the case of the willow, present a quite different appearance when in flower.

On the other hand, there are groups of animals, such as the common snail, in which both male and female organs exist in the same individual. Snails are therefore said to be *hermaphrodites* (from Hermes and Aphrodite), but they are not self-fertile; they pair as do other sexual animals.

Primary sexual characters

2. Sexual characters are those which distinguish sex. On analysis, we find that they are of two different sorts. The *primary sexual characters* are those which have to do with the sexual function itself, which is essentially the production of *gametes*. It is on account of this conception of sex that botanists object to speaking of male and female plants or flowers; they point out that these organisms give rise to the *gametophytes* or true sexes, which produce the gametes. If we object to this on the ground that the so-called gametophyte generation is so insignificant, they point out that in the higher flowerless plants it is conspicuous, being known as the *prothallium*. Ferns produce spores, which give rise to these prothallia, and these in turn produce the gametes.

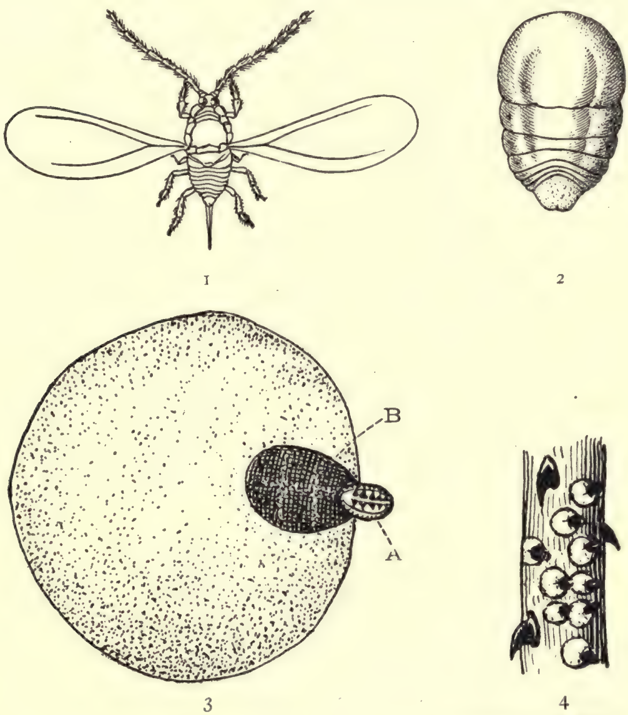
Secondary sexual characters

Secondary sexual characters are those which accompany sex, and are nearly always of some importance in relation to it. Such, for instance, are the bright plumes of certain male birds, or peculiarities of the voice. Although these two groups of characters appear so distinct, they do in fact grade into one another, unless we restrict the first entirely to the gamete-producing function. Structures existing for the preservation and nutrition of the zygote or fertilized cell can hardly be excluded from the group of primary sexual characters, since without them, in the animals in which they occur, reproduction would be impossible. From these there is actually every gradation, to characters which appear to have no functional relation to sex. Nevertheless, in a broad

sense, the distinction made is a valid and convenient one.

Why do sexes exist?

3. Many naturalists have discussed the question, why should the two sexes exist? The answer is not simple, yet from the fact that sexuality is such a widespread phenomenon, we cannot doubt that it has a meaning in relation to the preservation of life. At first it appears that reproduction depends upon sexuality,



Drawings by R. Weber

FIG. 17. The rose scale (*Aulacaspis rosæ*), an extreme case of sexual dimorphism. 1, Adult male, with 2 wings, 2 antennæ, 6 legs, but no mouth. 2, Adult female; legs, antennæ, and wings not developed, but mouth (on under side) well developed. This female never leaves the scale (3). The scale shows the cast skin of the larva at *A*, the second cast skin at *B*, and the white adult scale covering the female. 4 shows the scales on a rose branch, twice natural size.

but a little study of the more primitive organisms convinces us that this is not the case. That it does so in the higher animals must be only because there are certain advantages, for such animals, in this mode of reproduction. Our second thought may well be that it is not primarily a matter of reproduction at all but of diversity of vital functions. The male and female have different duties, and between them, like Jack Spratt and his wife in the nursery rhyme, they cover the field of opportunity. We observe that among the social insects such as the ants, there appear to be three sexes: males, females, and workers. The workers are not really another sex; they are sterile females, lacking sex, but they represent a further diversity of function. There is no doubt, of course, that diversities in the abilities and behavior of the sexes are useful in many cases. Out of the fact of sex has grown a multitude of consequences, which in man especially are of the greatest significance. Yet it is impossible to explain the origin and rise of sex on the basis of results which were millions of years ahead. Of what value is sex in its simplest form, when it is narrowed down to the primary function of producing germ cells which are capable of uniting to form a new individual?

Diversity resulting from conjugation

4. Professor H. S. Jennings found that even in such non-sexual animals as the Paramecium, conjugation increased variability. This is easily understood if we suppose that the germinal constitution of different individuals is not exactly alike. If one is *ABC*, the other *abc*, then after conjugation we may get *Abc*, or *aBC*, or *abC*, etc. Granting that increased variability is beneficial, in so far as it produces new combinations which may prosper under particular conditions, we can see how conjugation was justified. Its function, from the

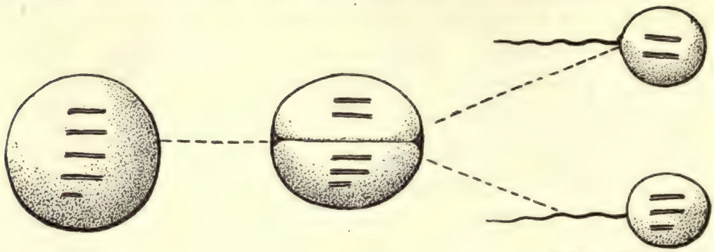
first, must have resembled that of trade. It was not necessary, but often advantageous. This, however, is not sex. Sex implies the production of gametes which have the reduced number of chromosomes. These gametes are diverse, the one produced by the male in animals small and motile, that produced by the female relatively large and incapable of propelling itself. Still, the outcome of the fertilizing process and all that goes with it is a shuffling of determiners, with a corresponding diversity in the members of the resulting generation. It is because of sex that scarcely any two human beings are alike, that life takes on such extraordinary diversity everywhere. This diversity has permitted *adaptation* to almost every kind of environment; has furnished, as it were, keys to open every door of opportunity. If we think of this as the principal meaning of sex in the scheme of evolution, we may regard the sexual *differences* as merely means to an end. The egg cell carries the cytoplasm with which to support the first stages of development; it cannot seek the sperm, nor could two egg cells, thus provided, seek one another. So the sperm, free from baggage, which the Romans truthfully called "impedimenta," can travel in search of its mate; but two sperms would not have between them enough nutrient substance to support the early cell divisions. The differences now appear to have a meaning, and it is interesting to note that those characteristics which distinguish the gametes, also more or less distinguish the sexes themselves in their relation to one another.

Sex and the variety of life

5. We may have our opinion concerning the utility of sex, but it is quite another matter to decide why individuals are male or female. Many opinions have been expressed, but it is only rather recently (1902)

Mechanism of sex determination

that much real light has been thrown on the subject. When it came to be realized that the chromosomes were



Drawing by R. Weber

FIG. 18. Diagram to show spermatogenesis, the small "sex-chromosome" going to one sperm of every two.

of prime importance in the study of heredity, these bodies were scrutinized with great care, in a considerable number of animals. It was found that the sperm cells of certain insects were not all alike, but were of two kinds, differing in the number of chromosomes. There was a peculiar chromosome, often standing a little apart, which existed in one of the kinds of sperm, not in the other. It was evident that in the reduction division this chromosome had no mate, and hence only one of every two sperms could receive it. Consequently just half the sperms possessed one more chromosome than did the other half. Further investigations showed that the peculiar chromosome, now called x, did often have a mate, usually smaller, which was named the y-chromosome. In such cases every other sperm contained an x, the rest a y. There were other modifications of the scheme, but the general outcome was as follows: Each of the egg cells contains an x-chromosome; when a sperm containing an x unites with it, then the zygote contains $2x$ and produces a female. When the sperm lacks an x, then the zygote comes to have x or xy, and produces a male. Although this was made out first in

insects, it is equally true of many other animals, apparently including man. Recent work has revealed a number of cases to which the above description is not applicable, but the principle remains the same; namely, that sex is determined at the moment of fertilization, by the number of *x*-chromosomes, or sex-chromosomes, which go into the zygote.

The *y*, when present, seemed to have no function at all; but C. B. Bridges has lately published an account of certain cases in *Drosophila* which appear to show otherwise. Owing to certain abnormalities in chromosome distribution, it was possible to produce males without the *y* which is normally present in that insect. They were quite ordinary in appearance, but absolutely sterile. Taking advantage of these same abnormalities, it was found that zygotes with *y* or *yy*, but no *x*, and also those with 3*x*, were unable to live.

It thus appears, on the face of this evidence, that sex is determined by the *amount* of a particular kind of chromatin, which exists in a special chromosome. One portion produces a male, two portions a female, while three are incapable of development. Is a female, then, all that a male is, and something more? Hardly so, for femaleness inhibits the development of male characteristics. Gametically, the female may be a product of the male determiner plus another, but in development the characters of the one are obviously not added to the characters of the other.

The arrangement provides that exactly half the offspring shall be male, and half female, on the average. The chances of an egg cell being fertilized by one or the other sort of sperm are even. Why, then, are the sexes not equal in number in all animals? There are various other factors entering into this matter; the chances of

living may differ, even when the zygotes formed are half of each sex. Cases are known among insects, in which the sperms of the male-producing type degenerate, so that only females are produced. Unfertilized eggs, developing parthenogenically, give rise to males. The quantitative difference between the sexes is thus maintained. Should it happen, in any case, that only part of the sperms degenerate or fail to function, the sex ratio will be disturbed.

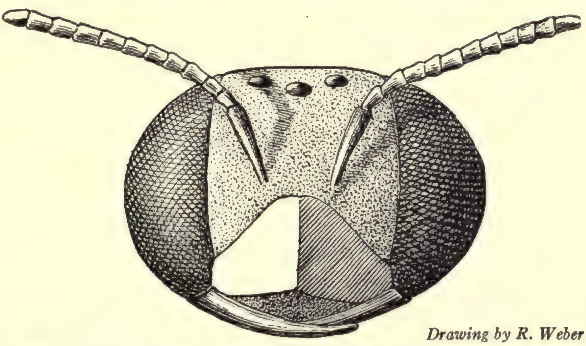
Sex-linked and sex-limited characters

6. Certain characters are said to be *sex-linked.* These are not the secondary sexual characters (*sex-limited*), and have no necessary connection with any of the sexual activities. Sex-linked characters are those for which the determiners are carried by the sex chromosome (x-chromosome). How can such a fact be ascertained, since, although the chromosome may be seen, no one can distinguish determiners in it? In the *Drosophila* flies, the normal color of the eyes is bright red. A variation with white eyes appeared, and Professor Morgan proved experimentally that it was sex-linked, in the following manner: A white-eyed female, mated with a red-eyed male, gave only red-eyed females and white-eyed males. These, crossed together, gave both red- and white-eyed of each sex. The theory is as follows: Red-eye and white-eye are allelomorphic, — that is, paired opposites in inheritance. Red is dominant over white. If these determiners are in the x-chromosome, then the white-eyed female has two "white" x's. The red-eyed male has one "red" x. Half the sperms of the male carry the "red" x, and produce females carrying one "red" and one "white" x. Red being dominant, such heterozygous females are red-eyed. The other half of the sperms carry no x, and unite with gametes from the females carrying one

"white" x. Such are males and are necessarily white-eyed. In the next generation the sperms from the male carry no red, but of the egg cells from the heterozygous female half carry red, the other half not. Each half is equally likely to be fertilized by a male- or female-producing sperm; hence there are both red- and white-eyed males and females. Similar facts were developed in numerous other cases, proving that the sex chromosome carries other determiners than that for sex, and at the same time confirming the sex chromosome theory.

Gynandromorphs, with characters of both sexes

7. Although sex is said to be determined by the germ plasm of the zygote, and therefore decided at the moment of fertilization, there are various apparent exceptions and complications. Among insects individuals occasionally appear which combine the characters of the two sexes in a remarkable way; these are called *gynandromorphs*. A certain kind of parasitic wasp not only has the sexes differently colored, but whereas the males are winged, the females are wingless. A specimen was found in which the right side showed the male characters, with wings, and the left those of the female,



Drawing by R. Weber

FIG. 19. Face of gynandromorphic bee (*Melissodes*), the clypeus showing the color of the male (light) on one side, of the female (dark) on the other.

apterous. In a kind of bee (*Melissodes*) the females have the face black, but in the males a large part of the face (the clypeus) is yellow. A specimen was collected in Texas, which had the clypeus half yellow and half black, the division between the colors perfectly sharp and definite. In other cases the sexual characters are variously combined, forming a sort of mosaic.

Various explanations have been given for these strange phenomena, but as Morgan has recently (1914) shown, it is almost certain that they are due to accidents in cell division at an early stage of growth. If at some early division, after fertilization, the sex chromosome fails to enter a particular cell, the tissue developing from that cell will appear as if the chromosomes in question had been absent from the start. Thus the determination of sex at fertilization is only determination in this sense, that it provides the machinery for the development of sex. If that machinery goes wrong, the expected results do not follow.

Determination of sexual characters through secretions

8. Among the vertebrates, especially, secondary sexual characters are determined by certain secretions which act upon the various parts of the body. In such animals the gynandromorphic phenomena could not occur. The development of the characters does not depend on the chromosomes in the tissue cells, but on the special activities of certain localized cells connected with the sexual organs. Consequently, as is well known, the removal of the sexual organs or their injury by disease results in profound changes, affecting different structures. It is not especially surprising that when the sexual organs of certain male animals are removed, special male characters, such as horns, fail to develop. We are more astonished, however, to find that in various birds the removal or degeneration of the

female organs leads to the appearance of male plumage. The female, in such cases, carries the determiner for male plumage, but its influence is prevented by an inhibitor which goes with femaleness. Professor Morgan has very recently made a remarkable experiment which shows that this inhibitor is not a necessary consequence of femaleness, but is associated with it. In the breed of fowls known as the Seabright bantam, the male bird is colored and has the feathers formed nearly as in the female, instead of showing the typical plumage of a cock. It occurred to Morgan that perhaps the inhibitor of typical male plumage had been developed in the sexual organs of the male as well as those of the female. He accordingly removed those organs from a male, which then developed feathers like those of cock birds of ordinary breeds!

Sexual characters of twins in cattle and sheep

9. The secretions or *hormones* which control the manifestation of sexual characters may so far influence sex as to produce sterility. It has been known from ancient times, that when cattle produce twins of opposite sexes, the female is usually barren. Dr. Frank R. Lillie of Chicago recently investigated this matter, and found that the facts were as follows: The twins, representing different zygotes, have at first their separate envelopes or chorions. As development proceeds, the chorions fuse, and the blood vessels of the two embryos unite to form a single system. It results from this that whatever secretions are produced by the one flow in the veins of the other. The hormones from the male, flowing through the body of the female, cause the suppression of the reproductive organs of the latter. Occasionally the envelopes of the two embryos remain unfused, and in such cases, as Dr. Lillie was able to demonstrate, the female is perfectly fertile. In sheep,

while the chorions fuse, the circulations of the twins remain distinct; hence the sexes are normal. It rarely happens among sheep that the female of a pair of opposite-sexed twins is sterile, and in such cases it must be supposed that there has been a fusion of the circulation.

CHAPTER TWELVE

NATURE AND NURTURE

1. CONTEMPLATING the characters of any living being, whether plant or animal, we may ask which are due to heredity ("nature") and which to environment ("nurture"). The answer to this question assumes great practical importance in relation to domestic animals and plants, and still greater when we come to consider man and all the problems of education, of morality, and justice. First of all, however, it is necessary to be quite sure what we mean by these terms. In a broad sense, heredity and environment are alike nature; but the custom has grown up of using "nature" to mean the inherited equipment, as when we speak of "the *nature* of the beast," or say, in the words of the old nursery rhyme, "dogs delight to bark and bite, it is their *nature* to."

Effects of heredity and environment

2. With this definition or limitation, the matter superficially appears rather simple, but it is in fact very complex and often puzzling. We cannot say that we came into the world as infants, with our "nature," and that every subsequent addition is due to "nurture," though in one sense this may be true. Most assuredly the environment provided our food, the source of all our growth. Not only this, but the physical substance of the living body is constantly wearing away, so that after a few years there is very little of the original material with which we were born. A little further inquiry shows us that long before birth we were growing, and absorbing nourishment, so that if we wish to go back to the actual beginning and ascertain what our "inheritance" was, we find that it was nothing more than a fertilized cell of the minutest size. Truly it

Favorable environment necessary for existence

seems that we started in business with very little capital, and have become almost everything we are by taking advantage of the environment. In our original phrase, it seems to be nearly all nurture and very little nature indeed.

Photograph by W. M. Goldsmith

FIG. 20. Two lots of potatoes raised by Mr. William M. Goldsmith at Gunnison, Colorado, in 1918. Both had the same parentage, but one lot was propagated from the largest tubers in the hill, and the other from the smallest. Similar tubers are shown at the base of each bucket. Both lots were given the same treatment. The yield shown in the buckets was 25 and 27 lbs., respectively, showing no superiority in the product of the large tubers. Potatoes are reproduced vegetatively from the tubers without change in hereditary qualities, except in the rare case of a bud sport or mutation. The experiment illustrates the non-inheritance of acquired characters. The little tubers were little because of differences in time of development or position, broadly speaking of nutrition, and not because they had inherited different qualities. There are, however, other forms of the potato genus which have invariably small tubers, and these will reproduce nothing larger, being controlled by heredity.

Dominance of the hereditary factors

3. We notice, however, that we are human beings, and that the offspring of such are always human. So also the progeny of elephants are elephants, of cabbages, cabbages. Why should this be so, if the environment is the principal thing? Heredity appears to contribute to the elephant a single minute mass of protoplasm of microscopic size; the whole vast body is built up out of the nourishment secured; should the latter not determine the size, form, and quality? On the contrary, the microscopic cell decides not merely that the creature shall be an elephant, and no other sort of beast, but also what

particular sort of elephant it shall be; perhaps even whether it shall be a good-natured, tamable elephant or a dangerous, vicious animal! I know a family of people in which a dimple in the chin has been inherited through five generations, though there was nothing peculiar, nothing having to do with dimples, in the "nurture" of all those persons. To such apparent trifles does the grip of heredity extend! Surely, then, it is all "nature," and "nurture" is a negligible factor!

Interrelations of hereditary factors in the individual

4. The matter is not so easily settled, though, for when we come to study inheritance in detail we discover that the individual has a bundle of inherited qualities. For each of these qualities, or rather determiners of qualities, all the others act as an environment. The individual is thus complex, and the total result comes from the interactions of many forces, internal and external. In man, at least, the inheritance is potentially richer than the possible development, so that choice partly determines the adult character. As Bergson states: "Life is a tendency, and the essence of a tendency is to develop in the form of a sheaf, creating by its very growth divergent directions among which the impetus is divided. This we observe in ourselves, in the evolution of that special tendency which we call our character. Each of us, glancing back over his history, will find that his child-personality, though indivisible, united in itself diverse persons which could remain blended just because they were in their nascent state; this indecision, so charged with promise, is one of the greatest charms of childhood. But these interwoven personalities become incompatible in course of growth, and, as each of us can live but one life, a choice must perforce be made. We choose in reality without ceasing; without ceasing, also, we abandon many things.

FIG. 21. The effect of environment on squash plants. The two plants shown were grown at Boulder, Colorado, from the same lot of seeds. On the left, the ground was left untilled; on the right, it was turned up and manured. Another squash, from the same lot of seeds, growing just behind the big one, also had fertile soil, and grew to a large size; but its fruits were green and worthless, because it was crossed with some other kind. The large plants are those which have had advantages in this world; have been to college, as it were. But sometimes, if the heredity is unfavorable, the environment is powerless to give satisfactory results.

The route we pursue is in time strewn with the remains of all that we began to be, of all that we might have become. But Nature, which has at command an incalculable number of lives, is in no wise bound to make such sacrifices. She preserves the different tendencies that have bifurcated with their growth. She creates with them diverging series of species that will evolve separately." (*Creative Evolution*, page 99.) Heredity provides the hand of cards, but ours may be the choice to play. Does heredity also determine that choice? In part, yes, but as every one knows, it is very largely determined by the influence of others, by opportunity, and lines of least resistance.

The inheritance of a dimple

5. As an illustration of the force of heredity and its independence of environment in certain cases, we may cite the inherited dimple in the chin of the P. family. The dimple is correlated with a depression in the bone

beneath. The facts were communicated to the writer by Miss P., one of his former students, in whom the dimple is very distinct. In the following pedigree the generations are marked (1), (2), etc., ♂ = male, ♀ = female, *D* = dimple present, *d* = no dimple. × = married, and the vertical line below shows the offspring. The P. family is of French-Scotch ancestry, the Scotch side from the Macdonalds.

(1) *D*♂ × ?♀

(2) *D*♂ × *d*♀

(3) *D*♀ *D*♀ *D*♂ *D*♂ *D*♂ *D*♂ *D*♂ *D*♂ *D*♂ *D*♂ × *d*♀

(4) *D*♀ *D*♀ *D*♀ × *d*♂ *D*♀ × *d*♂

(5) *D*♂ *D*♀ *D*♀

Dimple is evidently dominant, but in the fourth and fifth generations we should expect some non-dimple children. Their absence may be due to chance, just as the children of a given family may be all boys or all girls.

Other inherited qualities, such as musical ability, might appear much more irregularly, their successful development depending upon a favorable environment. Thus, while dimple is due to heredity, and appears in any environment which permits development and growth, success as a pianist requires not only favorable heredity but special environment. Other qualities, depending on the environment and not on heredity, such as ability to speak English rather than French, are not inherited at all. A person of French descent has as much difficulty in learning French as one of English descent, provided that he has had no more opportunity to hear it spoken. This in spite of the fact that his remoter ancestors for many generations may have spoken French.

CHAPTER THIRTEEN

SOCIAL LIFE

A society defined

1. Societies, whether among men or animals, are groups of individuals associated together for common ends. "Plant societies," sometimes referred to by botanists, are groups of plants growing together, but without the features of a true society; they are better called "plant associations." It is true that in forests the trees protect one another from the violence of the winds, and that in rather numerous cases different forms of plants coöperate for mutual benefit. For example, plants of the pea family have bacteria growing in their root tubercles; and these bacteria, being able to "fix" — or make part of an available chemical compound — the nitrogen of the air, are in turn highly beneficial to their hosts. Such intimate relationships between different species are defined by the term *symbiosis* (Greek, "living together") and are not properly called societies.

Coöperation of parts in single-celled organisms

2. Nevertheless, even in the lowest plants and animals the parts of the cell may be said to be joined together for common ends, the cell being a complex machine. Thus no life can exist without a sort of rudimentary socialization of the parts of the individual, and it is the interplay between these which makes life. The principle of coöperation may in this sense be said to have begun with life itself.

Coöperation of cells in many-celled organisms

3. In a still more obvious sense, socialization was manifested when the first two cells remained together, to make the beginnings of a many-celled animal or plant. Very soon the cells thus associated began to develop along different lines, and the several types of *tissues* were formed. A human being is an extreme and very complex example of this sort of *differentiation* and

specialization. The myriad cells of the body have their different functions to perfoım, and successful life depends upon coöperation. Death results from the failure of any one set of cells to do its work.

Social groups among the lower animals

4. Groups forming societies are found even among the lower forms of animal life. Thus among the Cœlenterates, the group of the sea anemones and jellyfishes, we have the zoöphytes (Greek, "animal plants"), which occur in groups so closely associated that we wonder whether they constitute one animal or many. The individuals of the zoöphyte "colony" are variously differentiated; some do the feeding, some the fighting (stinging), others the reproducing for the group. The reproductive members in many species become free, and float about as little jellyfishes, when no one doubts that they are separate animals. Thus socialization in these low forms of life is extreme, but is governed by instinctive reactions. We do not identify it with symbiosis, because the individuals, though very different, are all of the same species.

Social life among insects

5. Much higher in the scale, the ants and bees form complex societies, and here the fact of socialization is plain to any onlooker. Among the ants, for example, are males, females, and workers (sterile females), and sometimes special forms known as "soldiers." The latter have very large heads, but do not possess large brains to correspond. They are tremendous fighters, and sometimes when their jaws have closed on an enemy in bulldog grip they will permit their heads to be pulled off before they will let go. All these different forms of ants coöperate, each type fulfilling its own special tasks and serving the interests of the city, which is the ant hill. They make fewer mistakes than we do, because they are governed by instincts, or in other words react

Slavery made possible by instinct

in precise ways to particular stimuli, having little "freedom of the will." This dominance of instinct makes them equally reliable as workers, whether in their own nests or in those of other ants. Hence it has been possible for certain kinds to establish a system of slavery, by stealing the immature forms of other species and raising them to maturity. The "slaves," thus obtained, work quite as well in the colonies of their abductors as they would in their own. The peculiar ant called *Polyergus*, though a great fighter, has to depend for food entirely on its slaves. There is nothing but instinct to prevent the latter from running away and leaving their masters to starve, but they never do so. They are enslaved by their own natures.

Man's ancestors show little social life

6. Passing up through the lower vertebrates and mammals, in the line leading toward man, we find very little socialization; practically none until we come to the monkeys, which live in bands.[1] Had man never appeared, there would be no reason for connecting the highest types of life with relative perfection of social organization. Some intelligent being who might be discussing the matter can be thought of as saying: "Extreme socialization is very well for insects, such as ants, but is quite unsuited for vertebrates, especially the higher types; a loose form of organization, in bands or flocks, is often advantageous, but all experience is against carrying the principle to extremes." It could not be argued, however, that the method failed among the ants, for these are the most successful of insects, and literally own the earth wherever it is possible for them to live.

[1] Birds, wolves, prairie dogs, and other vertebrates occur in groups or flocks, but they do not form highly developed societies, nor do they belong to the series giving rise to man and his relatives, except in the very general sense of being vertebrates or mammals.

Development of human society

7. In the development of man the change of posture which permitted the hands to be used for making things, and the long period of infancy and youth which gave opportunities for education or "social inheritance," necessarily implied a certain weakness. As compared with other animals, man was a feeble beast, at first much greater in his possibilities than in his performance. Had he not become socialized, he must have become extinct; only through socialization could he realize his potential powers and turn his weakness into strength. The development of human society was guided by conscious purpose, and hence was progressive. No combination of mere instincts could have developed fast enough to save him, nor would it have left him free to advance. Ant societies have been doing for at least two million years what they do today; their social system is static and unprogressive.

The freedom of the will, and the obligation to decide

8. The human social unit, formed at first for protection against the elements and from enemies, developed through the specialization of the individual. This specialization, however, was much more plastic and variable than that of the ants. It left a large element of choice, and found expression in psychological rather than structural peculiarities. No one could call into being powers which were beyond the limits of his organism, limits set at the moment of fertilization. Yet each one found himself potentially able to do any one of many incompatible things, and hence not only had "freedom of choice," but was compelled to choose. The freedom he did not possess, and which the ant essentially has, was that of escaping decisions, of evading personal responsibility. The philosophical postulate that actually each choice made is determined by antecedent events, and hence not "free," may find logical

support; but it does nothing to save man from his everlasting dilemma, his perpetually recurring choice of good and evil. With the increasing complexity of his social life, this choice becomes still more important and more difficult, and organized education becomes necessary. The experiences of the individual are not sufficient to form the basis of his judgments, and were it not possible for him to find a short cut through education to the experiences of the race, modern civilization could not exist. The glaring defects in this civilization are largely due to the imperfections of the educational processes which are implied in the system; it is as though we had a complicated machine, parts of which were poorly constructed and out-of-date. So long as this condition existed, the very excellence of other parts would only increase the danger of disaster.

Origin of leadership

9. Owing to the inequalities of inborn endowment, it is not possible, even were the educational system perfect, to bring every individual to the same level of efficiency. It is not desirable to organize society on a basis representing the powers and capacities of the least efficient, hence leadership is necessary. Certain individuals do more of the thinking and planning than others, or do the more difficult work. There is no escape from this arrangement without lowering the social level, but in all ages this racial necessity has been made the excuse for predatory or tyrannical acts. Just as the imperfectly educated person is like a defect in the machinery, so also the imperfectly socialized but otherwise able individual is a menace to the state because he is trying to do two incompatible things at once. It is this division of activities which is referred to in the Scriptural saying that no man can serve God and mammon.

10. When, however, the leaders are essentially honest and socially minded, their leadership is still not without its possible disadvantages. The amount of leadership desirable depends upon a variety of circumstances, but it may be taken as axiomatic that the freedom of the individual should be as great as his capacity permits. It may even be better to have some things done poorly through personal initiative than comparatively well under direction, because the activities required bear fruit in other ways. Aside from this, observation indicates that there is a constant tendency to exaggerate the abilities of those who have assumed leadership, and to permit them to do a share of the social planning out of all proportion to the superiority of their intellects. They themselves, of course, are especially liable to this delusion. When a leader really is far in advance of his following, his greater sagacity is likely to be underestimated during his lifetime; but he whose powers are mediocre, and of whom all men speak well, is more likely to be thought, and to think himself, a king by divine right. It is not to be supposed that these conflicts, arising from social organization and the diversities of individuals, will ever be overcome; they are part and parcel of the interplay of human life, and constitute, as it were, the rules of the game. All we can do, or should wish to do, is to understand these rules and play up to the limit of our capacity.

Advantages and disadvantages of leadership

11. We have referred to the leadership by the highly endowed of those less so; but there is another and increasingly more important type of leadership, which depends mainly on environmental differences. In a complex society people become specialists, and he who has mastered what humanity knows about bacteria or balloons takes the leadership, in regard to his specialty,

Value of specialists to society

over even greater men occupied in other ways. We are told that this is an age of specialists, and it is certainly true that we are coming to depend more and more on leaders of this class. The more eminent, at least, also lead by virtue of inborn ability, but the group as a whole is a product of particular forms of education. The arrangement permits society to act on a basis of intelligence far exceeding that possible for a single citizen, and through our means of communication the wisdom of the specialists is almost immediately available to all who are able to profit by it. Consequently, it becomes worth while to expend large sums of public money in support of scientific research, whereby truths are ascertained and become common property. We must add, however, that even this form of leadership, so beneficial in most respects, is not without its dangers. Specialists who devote themselves to the intensive study of particular problems are likely to become narrow-minded, so that they fail to see the relations between their own discoveries and things in general. Their truth is true, but is not the whole truth. Thus the fruits of special research need to be reconsidered and restated in the light of a broader philosophy, and it would be a misfortune if all the ablest members of society restricted themselves to narrow though productive fields of intellectual activity.

CHAPTER FOURTEEN

CHARLES DARWIN

1. CHARLES DARWIN was born in 1809 at Shrewsbury in England. His father was a doctor of medicine, and his grandfather, Dr. Erasmus Darwin, was a noted poet and philosopher, with ideas on evolution. The philosophical verse of Erasmus Darwin, written in a style which seems artificial in these days, found many admirers in the eighteenth century. Today we care little for the work as literature, but are interested in the mental tendencies exhibited, in connection with those found in the far more illustrious grandson. The faculty of imagination, which may make a poet and dreamer, is no less valuable to a man of science. Charles Darwin came of good stock, and had many competent ancestors in addition to those just mentioned. His mother was one of the Wedgwoods, a family noteworthy in many respects, but now best remembered in connection with the beautiful pottery made at the Etruria works in Staffordshire. An elaborate pedigree of the ancestors of Darwin has lately been issued by the Francis Galton Laboratory for National Eugenics, and it appears that these include such persons as Charlemagne and Alfred the Great. **Darwin's ancestry**

2. When eight and one half years of age, Darwin was sent to a day school at Shrewsbury. By this time his taste for natural history, and more especially for collecting, was well developed. He tried to make out the names of plants, and collected shells, coins, minerals, and many other things. He remarked in after years that the passion for collecting was clearly innate, as none of his sisters or his brother ever had this taste. It was no doubt stimulated by the prevalent custom in **Boyhood and early traits**

English schools of collecting various objects, so that a new boy, on entering, is asked, "*What* do you collect?"

From an old engraving

FIG. 22. Erasmus Darwin, grandfather of Charles Darwin.

Many who have begun by collecting stamps, birds' eggs, or butterflies, have developed into good amateur naturalists. When somewhat older, Darwin began to collect beetles, and not only obtained a fine series of these insects, but was able to send rare specimens to the entomologist, Stephens, who mentioned them in his work on British Entomology. Thus the "mere collector" came to realize that he could contribute something to the progress of science.

The old-fashioned English school

3. In 1818 Darwin went to Dr. Butler's school at Shrewsbury, and remained until he was sixteen years old. He had a very poor opinion of the instruction, but it is evident that he made more progress than the statements in his autobiography would suggest. It is difficult for us to appreciate the narrowness of the curriculum of an English school of those days, with its entire emphasis on the classical languages and theology, and almost total neglect of science. If the product of such an educational factory was better than might have been expected, it was due to the invigorating influences outside the classroom and in the home. On the other hand, the translation of Latin not only served to make the pupil familiar with that language but also contributed largely to the formation of a clear and good English style, — a matter of the first importance for those who, like Darwin, had something of value to say.

Darwin's medical studies at Edinburgh

4. In October, 1825, Darwin went up to Edinburgh University to study medicine. Here he remained two years, and although he never took a medical degree, he must have acquired a considerable knowledge of scientific subjects. He wrote home that the lectures on human anatomy were as dull as the lecturer himself, and the subject disgusted him. In after years he deeply regretted that he did not dissect more diligently. Fortunately, he made the acquaintance of several young men interested in zoölogy, and the year following his arrival at the University he read a paper before the Plinian Society, announcing a zoölogical discovery of his own.

Cambridge University and Professor Henslow

As it was evident that Darwin would never make a doctor, he was taken from Edinburgh and sent to Cambridge, with the idea of turning him into a clergyman. At Cambridge University he was entered at Christ's College, and although he passed his ex-

aminations without difficulty, he afterwards expressed the opinion that much of his time was wasted, so far as academical studies went. Nevertheless, his scientific interests were further stimulated by Professor John Stevens Henslow, a botanist and all-round naturalist, who rambled with him into the country around Cambridge, and became his intimate friend. The dons used to speak of Darwin as "the man who walks with Henslow."

The voyage in the *Beagle*

5. In 1831, on returning from a geological tour in Wales, Darwin found a letter from Henslow stating that the *Beagle*, a vessel of the Royal Navy, was about to circumnavigate the globe, for the purpose of surveying and charting various coasts. Captain FitzRoy wished to have a naturalist on board, and was willing to give up part of his own quarters to a competent young man who would serve without pay. Could Henslow recommend some one? He could and did recommend Darwin, whereupon arose a great controversy in the latter's family. Charles was "instantly eager to accept the offer," but his father strongly objected, and regarded the plan as so preposterous that he added: "If you can find any man of common sense who advises you to go, I will give my consent." This man was found in Uncle Wedgwood of Maer, and the arrangements were at length made. There still exists a memorandum by Darwin, detailing the objections raised, as follows:

"1. Disreputable to my character as a clergyman hereafter.

"2. A wild scheme.

"3. That they must have offered to many others before me the place of naturalist.

"4. And from its not being accepted there must be some serious objection to the vessel or expedition.

"5. That I should never settle down to a steady life hereafter.

"6. That my accommodations would be most uncomfortable.

"7. That you [his father] should consider it as again changing my profession.

"8. That it would be a useless undertaking."

This list is extremely characteristic of Darwin, who had the habit of marshaling impartially the arguments for and against any proposition. Thus it has come about that those who may wish to find reasons against Darwin's opinions, look for them in Darwin's works. Undoubtedly this careful survey of the pros and cons gave to Darwin's writings much of their extraordinary power; he never allowed himself to be carried away by an idea, unchecked by the objections which careful and prolonged thought could muster against it.

The objections to the voyage were not sustained in the event, except perhaps No. 6; Nos. 1 and 7 ceased to be objections. The hardships were accentuated by a constant tendency to seasickness, and it was supposed that this had to do with the physical defects which made Darwin a semi-invalid for the rest of his life. Since, however, a similar weakness existed in another member of the family, who did not go to sea, it is probable that there was a constitutional defect, which may have been aggravated by the five years' voyage.

Darwin's enjoyment of nature

6. Darwin's journal of the voyage has been published in what is now one of the classics of travel. As we read, it is difficult to realize that it was written by a young man recently graduated from college. Its style is so mature, its thought so profound, and the knowledge of zoölogy and geology shown is so remarkable, that we

should have to search long to find a parallel. No better example could be found of the force of innate ability. There are few passages in the literature of exploration as charming as this description of the first day in a Brazilian forest:

"The day has passed delightfully. Delight itself, however, is a weak term to express the feelings of a naturalist who, for the first time, has wandered by himself in a Brazilian forest. The elegance of the grasses, the novelty of the parasitical plants, the beauty of the flowers, the glossy green of the foliage, but above all the general luxuriance of the vegetation, filled me with admiration. A most paradoxical mixture of sound and silence pervades the shady parts of the wood. The noise from the insects is so loud, that it may be heard even in a vessel anchored several hundred yards from the shore; yet within the recesses of the forest a universal silence appears to reign. To a person fond of natural history, such a day as this brings with it a deeper pleasure than he can ever hope to experience again. After wandering about for some hours, I returned to the landing place; but, before reaching it, I was overtaken by a tropical storm. I tried to find shelter under a tree, which was so thick that it would never have been penetrated by common English rain; but here, in a couple of minutes, a little torrent flowed down the trunk. It is to this violence of the rain that we must attribute the verdure at the bottom of the thickest woods; if the showers were like those of a colder clime, the greater part would be absorbed or evaporated before it reached the ground."

Thus, throughout the voyage, æsthetic enjoyment and keen analysis went hand in hand, and it is not surprising that the scientific results were great.

7. The *Beagle* sailed down the coast of South America and through the Straits of Magellan; then northward up the coast of Chile, to the Galapagos Islands; thence across the Pacific, where Darwin made his famous study of coral islands, to Australia and New Zealand; from Australia across the Indian Ocean to Cape Colony, then once more across the Atlantic to Brazil, and home. In South America Darwin made long trips overland, doing a great deal of important zoölogical and geological work. He discovered the bones of many remarkable extinct animals, which were afterwards described by Professor Owen. A skull representing a new suborder of mammals was found in the yard of a farmhouse, where small boys were amusing themselves by throwing stones at it. Among living creatures perhaps the most interesting was a new species of South American ostrich, which received the name *Rhea darwinii.* In the Galapagos Islands, Darwin noted that the different islands had distinct species of birds and reptiles, and that the degree of resemblance between these species was roughly in proportion to the distance between the islands. This caused him to begin thinking definitely about the mutability of species, though he had as yet no theory or distinct opinion.

Discoveries in foreign lands

8. In October, 1838, Darwin chanced to read the Essay on Population, by Malthus, which was then attracting a good deal of attention. In this work it was pointed out that populations tended to increase, and consequently press on the means of subsistence, which must be limited. Hence the process could not go on indefinitely. Darwin relates that: "Being well prepared to appreciate the struggle for existence which everywhere goes on, from long-continued observation of the habits of animals and plants, it at once struck me that

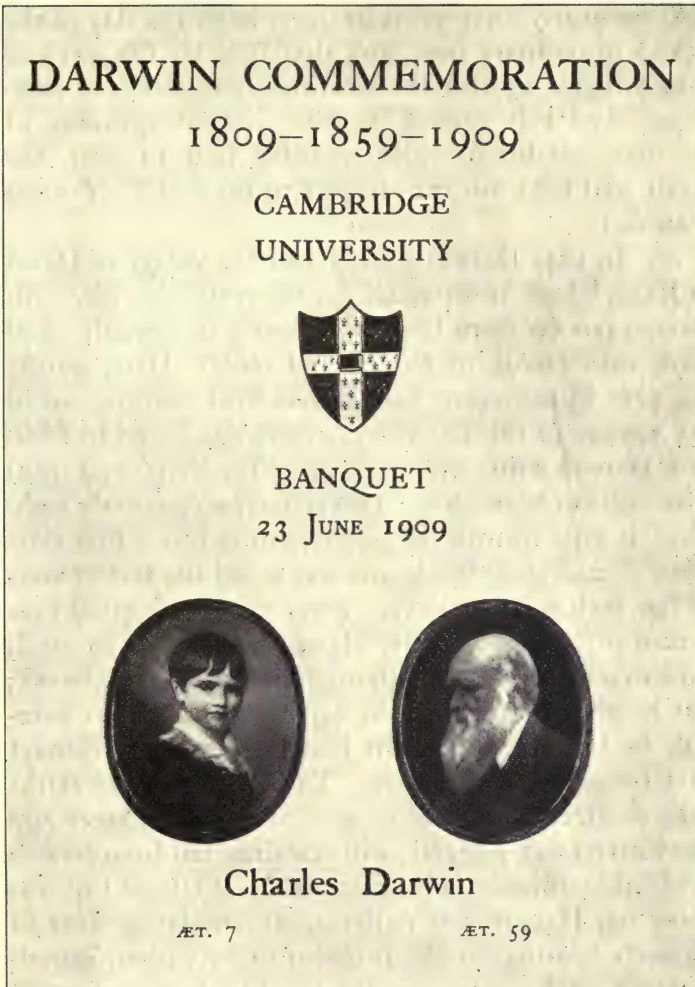
Malthus on Population, and the germ of the idea of natural selection

under these circumstances favorable variations would tend to be preserved, and unfavorable ones to be destroyed. The result of this would be the formation of new species. Here, then, I had at last got a theory by which to work; but I was so anxious to avoid prejudice, that I determined not for some time to write even the briefest sketch of it." Even before reading Malthus, he had dimly perceived the consequences of non-adaptation to surroundings, but now the matter became relatively clear and definite in his mind. In 1842 he wrote a rather full but rough statement of his views, which he did not attempt to publish. It was printed at the time of the Darwin Celebration at Cambridge in 1909, and in it we can see the foundations of *The Origin of Species*, published seventeen years later, in 1859.

Emma Darwin

9. In 1839 Darwin married his cousin, Emma Wedgwood. The union was in all respects a happy and fruitful one. Mrs. Darwin, though not scientific, was a person of quite unusual ability and character, and her devotion to her husband is described by one of her sons:

"If the character of my father's working life is to be understood, the conditions of ill health, under which he worked, must be constantly borne in mind. No one, indeed, except my mother, knows the full amount of suffering he endured, or the full amount of his wonderful patience. For all the latter years of his life she never left him for a night; and her days were so planned that all his resting hours might be shared with her. She shielded him from every avoidable annoyance, and omitted nothing that might save him trouble, or prevent him from becoming overtired, or that might alleviate the many discomforts of his ill health. I hesitate to speak thus freely of a thing so sacred as the lifelong devotion which prompted all this constant and tender



DARWIN COMMEMORATION

1809–1859–1909

CAMBRIDGE
UNIVERSITY

BANQUET
23 JUNE 1909

Charles Darwin

ÆT. 7 ÆT. 59

FIG. 23. Reproduction of cover of the Darwin Memorial Dinner souvenir, commemorating the one hundredth anniversary of Darwin's birth and the fiftieth anniversary of the publication of his greatest work, *The Origin of Species*.

care. But it is, I repeat, a principal feature of his life, that for nearly forty years he never knew one day of the health of ordinary men, and that thus his life was one long struggle against the weariness and strain of sickness. And this cannot be told without speaking of the one condition which enabled him to bear the strain and fight out the struggle to the end." (*Francis Darwin.*)

Monograph on barnacles

10. In 1842 Darwin settled near the village of Down in Kent, where he remained for the rest of his life. Although not far from London, it was a thoroughly rural spot, with plenty of flowers and birds. Here, during the next fifteen years, the various works arising out of the voyage of the *Beagle* were completed, and in addition Darwin wrote a monograph of the living and fossil Cirripedia or barnacles. This latter, being strictly technical, is unknown to the public, but it was a first-class piece of zoölogical work, and has stood the test of time as few such writings have. Some critics regretted that a man of Darwin's ability should have spent so much time describing and classifying innumerable specimens; but he always said that the experience was most valuable to him, as it brought him into intimate contact with the problem of species. The naturalist who shirks such drudgery, in order to give his time to larger and more attractive projects, will certainly fail from lack of detailed knowledge of his materials. While all this was going on, Darwin was patiently accumulating data of all sorts bearing on the problem of evolution, experimenting on his own account, reading books of every kind, and corresponding with people all over the world who might be able to help him with facts. Yet he did not publish, and confided his views to only a few of his most intimate friends.

Da-win and Wallace

11. The publication of Darwin's theory was finally brought about by an extraordinary coincidence. Alfred Russel Wallace, a naturalist then traveling in the Malay Archipelago, was attacked with malarial fever when at Ternate in the Moluccas. During his periods of prostration he had time to think over problems which interested him, and his mind followed along the very lines which Darwin's had in 1838. He also had read Malthus on Population, and like Darwin was well prepared by his great knowledge of living nature to appreciate the struggle for existence. He immediately perceived that he had hit upon a great principle, and as soon as he was well enough wrote out a rather full statement of it, with a view to publication. Wondering what he should do with the paper, he thought of Darwin as a man who would be likely to understand and appreciate the argument. So he forwarded the manuscript to him, asking him to have it published by some society if it seemed worth while. Darwin was amazed to read an account of the very theory he had been elaborating for so many years, in words practically identical with those he would have used himself. Here was a chance for rivalry, but it is pleasant to record that the two men were rivals only in the sense of each endeavoring to give fuller credit to the other than was claimed. Darwin was so conscientious that he at first wished to publish Wallace's paper and say nothing about his own labors. For, said he, "it was by the merest accident that Wallace sent his paper to me. Had he sent it elsewhere, it would have been printed, and he would have had priority, for I had no intention of publishing at present." Fortunately he consulted Sir Charles Lyell, the geologist, and Sir Joseph Hooker, the botanist, his two best scientific friends, who already knew about his work. They pro-

posed that Darwin should prepare an abstract of his views, and this, together with Wallace's paper, should be read before the Linnæan Society of London. This was done on July 1, 1858. Fifty years later, the Society celebrated the event in a special meeting, which Wallace and Hooker attended. Wallace, when he came to write his great book on evolution, called it *Darwinism.*

The Origin of Species

The next year, 1859, saw the publication of Darwin's book, *The Origin of Species*, and immediately the whole civilized world was agog with discussions on evolution and its relation to religious belief. Darwin found himself in a whirlwind of controversy, in which he was bitterly assailed and vigorously defended; but he kept out of the arena and quietly continued his researches. His friend, T. H. Huxley, pursued a very different course. A brilliant naturalist and master of English, he delighted to battle for what he understood to be right, and appeared here and there, on the platform and in the press, in defense of the new theory of evolution. It was very largely owing to Huxley that the new doctrine became so widely understood. Ultimately Darwin's victory was practically complete. Almost all living naturalists, except the oldest, were converted. The Church, at first bitterly hostile, became acquiescent. After Darwin's death, when a statue was erected to his memory in the great hall of the Natural History Museum, the three chief partakers in the ceremony were the Prince of Wales (afterwards King Edward VII), the Archbishop of Canterbury, and Professor Huxley.

Varied studies in later years

12. The last twenty years of Darwin's life, from 1862, were occupied by labors so varied and important that it would be difficult to understand how they could be undertaken by one in robust health, and it is marvelous that they should have been performed by an

invalid. Possibly the ill health itself had a certain advantage, for it compelled Darwin to spend a large part

From an engraving

FIG. 24. Thomas Henry Huxley.

of each day resting, and no doubt turning over in his mind the various problems connected with his work. Most of us are so active, rushing to and fro, that we have not sufficient time for thought. In continuation of the work on the theory of evolution appeared in 1868 *The Variation of Animals and Plants under Domestication*, and in 1871 *The Descent of Man*. The former gave an abundance of data concerning the phenomena of variation, and the effects of selection by man; the latter

discussed the evolution of man in general, and set forth the supplementary theory of sexual selection. In 1872 appeared *The Expression of the Emotions in Man and Animals*, in which it was shown that corresponding muscles existed, which in contraction expressed more or less similar feelings. Thus a certain psychological continuity in evolution was established, corresponding with a morphological one. Observations on his own children in early infancy were included in this study. There was also a series of important botanical works, concerned with the structure and fertilization of orchids (1862), insectivorous plants and the movements and habits of climbing plants (1875), the effects of cross- and self-fertilization (1876), different forms of flowers on plants of the same species (1877), and the power of movement in plants (1880).

Earthworms The last book, published in 1881, was on *The Formation of Vegetable Mould, through the Action of Worms.* Darwin had observed that objects left on the ground in England disappeared after a period beneath the earth, and seeking the cause, noted that earthworms were continually bringing soil to the surface as a result of their feeding and burrowing operations. This turning over of the soil is of great importance from an agricultural point of view, and the extent to which it goes on was proved by a long-time experiment in which the power of worms to bury objects was thoroughly tested.

Darwin died on April 19, 1882, and was buried in Westminster Abbey, a few feet from the grave of Sir Isaac Newton.

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CHAPTER FIFTEEN

VARIATION

1. We say that things are "as like as two peas," but two peas are not exactly alike. Everywhere among living beings we find variation; the individuals of a species differ in various ways from one another. Some creatures are much more variable than others; characters which separate species in one group may only distinguish individuals in another. Sometimes one stage is more variable than another; differently colored caterpillars may produce a very uniform lot of moths, as in the case of the white-lined sphinx. In other cases the immature stages are very uniform, but the adults vary.[1] Even when the variations are many and important, they follow certain lines, they are not indiscriminate. Consequently, when a particular sort of variety has been found in one species, we expect to see similar variations in related species. What the coneflower has done, the sunflower will do.

Variability universal

2. These variations, though all classed under one general heading, really represent several quite different phenomena. Theoretically we distinguish the following:

a. Variations due to changes in the germ plasm itself, or "original variations." These may be due

Different kinds of variation

[1] For beautiful illustrations of variations in caterpillars and moths, see Packard's work on the Saturniidæ, or great silk moths, in *Memoirs National Academy of Sciences*, Vol. XII (First Memoir), 1914. For variation in snails and slugs, see the colored plates in J. W. Taylor's *Monograph of the Land and Freshwater Mollusca of the British Isles*, or H. A. Pilsbry's work on Liguus, in *Journal of Academy of Natural Sciences of Philadelphia*, Vol. XV (2d Series), 1912. All these works illustrate the subject in color in the most exquisite manner. Any dealer in shells will supply series of *Helix nemoralis* and various marine shells, illustrating variation. Leaves and flowers (especially garden flowers) afford endless examples.

either to the addition of something to a determiner, or the loss of something, or conceivably to a shifting or shuffling of what is already there. Such a variation might occur in a determiner, through some chemical change in the protoplasm, and if recessive to the normal, produce no visible effect for hundreds of generations. It is therefore very difficult to say that a variation is "new," in a genetic sense. Even if we are sure that we have witnessed its first appearance on the stage, we may not know how long it has been waiting behind the scenes.

The discovery of multiple allelomorphs is significant in this connection. These are various determiners which appear to occupy exactly the same place in the same chromosome, and therefore cannot coexist in a gamete. The inference is very strong that these are actually mutations of a single original substance. A good example is found in the fly *Drosophila*, in which several different eye colors appear to be due to modifications of a single determiner. No gamete can carry more than one of these modified factors, and only two can coexist in a zygote.

b. Variations due to the loss of a determiner. Since Bridges has shown that a fragment may disappear from a chromosome, this type of variation is evidently possible. In numerous cases the allelomorphs (alternative characters) are to each other as plus and minus, positive and negative, and this fact has given rise to the "presence and absence theory." According to this view, the recessive is simply the absence of that which is represented by the dominant.

The fact of multiple allelomorphs throws new light on this matter, and we must doubtless say that the recessive determiner is not simply a vacant spot, but is a real factor which does not function as does the dominant. Hence this class of cases falls under our group *a*, rather than under the present group. Still, we must admit that sometimes there is actual loss of substance instead of modification, and there is reason for thinking that this may very rarely be brought about by environmental factors. There may be, in some cases, a selective destruction of the items of inheritance.

The above two types of variation are the most difficult to study and understand, but also the most important, since they will permanently modify the material of inheritance. Could we bring them about experimentally, we could practically produce new species. Even then, we could work along only certain lines which the character of the germinal substance permits, just as the chemist can make only certain compounds. It is probably fortunate that man has not been able in this manner to play the part of a creator; he would doubtless have made a mess of things. Nature may be "blind," but working in the long run and the fullness of time, she does her work better than we could hope to imitate.

New combinations of inherited qualities

3. Two other classes of variations have nothing to do with any change in the germ plasm itself.

c. Variations due to new combinations. These have been discussed under Mendelism and the Red Sunflower. It is evident that they will break up again, forming still other combinations, except when they become homozygous. In the

latter event, practically new constant forms may arise, representing no new factors but the old factors newly distributed. They are like new words, formed out of the old letters of the alphabet. It is probable that this process has been a factor in evolution.

Effects of environment

d. Variations due to environmental conditions acting on the body or mind, such as education, the effects of starvation, cuts or wounds of any kind, and so forth. These are not inherited. Although this kind of variation has no direct significance for evolution, it is not without its importance. Except in the case of purely external injuries, the variation observed is only *in part* due to environment. That is to say, it represents the *response* of the organism to certain conditions, and the nature of this response is determined by heredity. The ability to respond, as in education, is part of the inherited adaptability of the animal. Now this will often be a prime factor in the struggle for existence, enabling the creature to survive where others, less ready to become modified, will perish. In the case of man, especially, all his higher achievements are conditioned by his extraordinary *educability*, and the educational process has to be repeated in each generation.

When environmental conditions (e.g., alcohol) affect the germ plasm, there may be results appearing in the next generation, as we shall see below.

Varieties, aberrations, forms, and subspecies

4. In zoölogical and botanical nomenclature, the word "variety" is used very loosely. The student usually has to deal with preserved specimens, and does

not know how the variations have been brought about, though he can often reason from analogy. Among birds and mammals, especially, it has become customary to recognize *subspecies*. A subspecies is a phase or form which is reasonably true to type within a given area, but at one or more points intergrades with its allies occupying adjacent territory. As Beebe has shown in the case of birds, the peculiarity (e.g., a darker or lighter color) *may* be due to the immediate effects of environment, and the intergradation may be merely the expression of the intergrading climatic conditions. On the other hand, Sumner, experimenting with subspecies of wild mice, has found genuine hereditary differences. Mere inspection would not show which kind of "subspecies" we were dealing with. Suppose the differences to be inherited, the intergradation where two types meet may be due to hybridization. Entomologists recognize varieties and *aberrations*. The aberration or "sport" is supposed to occur occasionally, here and there. It may be known only by a single specimen, though the species to which it belongs is common. It is found, however, that the same kind of difference may distinguish an aberration in one place, and a local race or subspecies in another; and exactly the same thing is true of plants. Botanists use the word "form" or "forma" to designate minor varieties, but with no regard to their genetic significance. Ultimately the nomenclature of varieties will have to be revised in the light of genetic research, but it is not possible to do this thoroughly at present.

CHAPTER SIXTEEN

ALCOHOL AND HEREDITY

Supposed inheritance of alcoholism

1. Is "alcoholism" inherited? This question has been much debated, but it has been difficult to reach a definite conclusion. An affirmative answer is suggested by such instances as the following. A normal woman married a normal man, and the three children were all normal. Her husband died, and she married a drunkard. The three children from this union were all defective, two being drunkards. The second husband died, and again the woman married, this time a sober man. The children produced were sound and normal. Obviously, it seems, the children of the second marriage inherited their father's alcoholism. But what did they inherit? There is no proof that the large quantities of alcohol consumed by the father *caused* the alcoholism of the children. It is at least as likely that the father himself was defective, and his addiction to alcohol was an effect rather than a cause. Perhaps the children would have shown defects had there been no such substance as alcohol. As a matter of fact, in the case cited, they did show other defects than a tendency to drunkenness. One never developed properly, and two were tuberculous. The question, "Is alcoholism inherited?" thus assumes a new meaning. We used to think that consumption or tuberculosis was inherited, but it is now known to be due to a particular bacillus. What *is* inherited is a susceptibility to the attacks of this bacillus. Of course, when the bacillus is present, this comes to the same thing in a practical sense as if the disease itself were inherited. So also with alcoholism. If it is the tendency to succumb to temptation in the presence of alcohol which is inherited, then "alcoholism" may be "inherited" in the same sense that consumption is.

Alcoholism and feeble-mindedness

2. Miss Anne Moore some years ago prepared an interesting report on the feeble-minded in New York, and the facts set forth have a direct bearing on the problem of alcoholism. She quotes from the report of the British Royal Commission on mental defectives, and shows that it agrees with the American results. The Royal Commission found that over 62 per cent of all chronic inebriates were mentally defective, and that such defective persons reacted to the effects of alcohol more readily than normal ones. Miss Moore found that alcoholism was closely connected with various kinds of mental deficiency. It became a deciding factor in many cases, because it brought those who had poor natural endowments below the level of efficiency. Dr. H. H. Goddard, in his recent (1914) book on *Feeble-mindedness*, discusses this problem at some length. He reaches the following conclusion: "Everything seems to indicate that alcoholism itself is only a symptom, that it for the most part occurs in families where there is some form of neurotic taint, especially feeble-mindedness. The percentage of our alcoholics that are also feeble-minded is very great. Indeed, one may say without fear of dispute that more people are alcoholic because they are feeble-minded than vice versa."

Experiments with guinea pigs

3. Thus the matter might have rested, but for the work of the experimentalists. It is not possible to experiment with man, and the most carefully collected statistics are open to the objection that they represent the effects of various causes. Dr. Charles R. Stockard of New York undertook a series of investigations on guinea pigs, and obtained decisive results which are now famous. Guinea pigs reproduce so rapidly that it is possible to have many successive generations under observation, and satisfy oneself that the stock used is

normal. Under ordinary circumstances, they do not drown their sorrows in alcohol; there are no "alcoholic" families, nor is there any alcoholic past to complicate matters. The reactions of these animals ought to be perfectly naïve and natural. In order to avoid the complications arising from indigestion, Dr. Stockard gave the alcohol in the form of vapor, which the guinea pigs inhaled for definite periods. The individuals thus treated often became blind, from the effect of the alcohol on the surface of the eye, but in other respects they were little if at all injured. After a long period of treatment they remained fat and vigorous. Nevertheless, *their offspring plainly showed that they were affected by the alcoholism of their parents.*

Defective young from alcoholized parents

4. In the first place, the alcoholized individuals produced fewer young, and of these very many were stillborn, or died not long after birth. *The survivors were many of them markedly defective.* The defects principally concerned the central nervous system and special sense organs. Tremors and paralysis were very common, as also were defects of the eyes. In extreme cases the entire eyeballs and optic nerves were absent in the descendants of alcoholized animals. As the size of the litters was reduced through so many premature deaths, it sometimes happened that rather strong animals were produced in badly alcoholized lines. This resulted from the advantage gained from being the only one in a litter, and thus getting all the nutriment available.

Results of injury to germ cells of male parent

5. It might be supposed that since the young are developed in the body of the mother, the condition of the mother, resulting from the alcohol, would be the decisive factor. Thus it would not be a matter of inheritance at all, in the proper sense, but only of injury to the young animal before birth. Dr. Stockard's experi-

ments gave an exactly opposite result. *There was a larger proportion of degenerate, paralytic, and grossly deformed animals descended from the alcoholized males than from the alcoholized females.* In other words, the sperm cells were more sensitive to the poison than the egg cells. It is a marvelous thing, considering the minute size of the sperm, that this almost infinitesimal particle should be affected in a definite way, so as to produce very conspicuous results in the animal to which it in part gives rise. This is of course only an aspect of the familiar marvel of heredity, but being new, it astonishes us more.

Injured germ plasm affects the offspring

6. We may now return to our first question. In the light of Dr. Stockard's experiments, is alcoholism inherited? The offspring of the alcoholized guinea pigs were of course not alcoholics; they showed various defects, including low vitality. *They showed characters not present in their alcoholized parents at all.* How, then, can we speak of inheritance? What really happened in these cases? The alcohol, penetrating to every part of the body, injured the substance of the germ cells. The germ plasm was directly affected, and its functions were impaired. There was no tendency to produce new varieties of guinea pigs; the effects were pathological, such as might be produced by poisonous substances in any living tissues. It simply comes to this: the germ cells, with their chromosomes and the rest, are, after all, living protoplasm. They are not able to resist injurious influences in every case, though their power of resistance may be great. The history of life shows us how germinal complexes have retained their substantial identity for ages, unmodified or little modified by all the vicissitudes of existence. Yet they have not wholly charmed lives; they may be injured by the direct action of cer-

tain substances or conditions, so that the individuals they produce, if they produce any, are below the normal standard.

Injury continued to third and fourth generations

7. The germ plasm is the vehicle of life which continues from generation to generation. Will it recover from the injury, or will the effects continue "unto the third and fourth generation"? Stockard records that "the mating records of the descendants of the alcoholized guinea pigs, though they themselves were not treated with alcohol, compare in some respects even more unfavorably with the control records than do the data from the directly alcoholized animals." To be specific, of 194 matings of *non-alcoholized* offspring of alcoholized parents, 55 resulted negatively or in early abortions; 18 stillborn litters of 41 young occurred, and 17 per cent of these stillborn young were deformed. One hundred and twenty living litters contained 199 young, but 94 of these died within a few days and almost 15 per cent of them were deformed; while 105 survived, and 7 of these showed eye deformities.

These defects continue even to later generations. Dr. Stockard goes on: "The records of the matings of F_2 animals (F_2 means second filial generation, or grandchildren of the original parents) are still worse, higher mortality and more pronounced deformities, while the few F_3 individuals which have survived are generally weak and in many instances appear to be quite sterile even though paired with vigorous, prolific, normal mates."

Results with fowls contradictory: the offspring of alcoholized birds superior

8. After reading the accounts of Stockard's experiments, we turn to the still more recent work of Dr. Raymond Pearl on fowls, and are astonished to find that his results appear to be contradictory. The methods used with the fowls were parallel with those

employed on the guinea pigs, and naturally we should expect to get similar results. In one respect there is complete agreement. The proportion of fertile eggs was reduced by subjecting the parents to alcohol; the higher the dosage the smaller the number of zygotes formed. On the other hand, the number of embryos which after being formed died before hatching, and the number of individuals dying after hatching, was actually *less* among the offspring of alcoholized than untreated birds. When both parents were alcoholized, the average weight of the offspring at hatching was greater than when one or neither received treatment. The superiority of the offspring of fowls subjected to alcohol was maintained during their subsequent development, and they showed no greater proportion of abnormalities than the controls.

Explanation of contradictory results

9. How can such contradictory results be explained? Dr. Pearl supposes that the essential facts are about as follows: The gametes or germ cells vary in their vitality, and are not equally affected by any deleterious agent. Consequently, on treating the parents with alcohol or any similar substance which reaches the germ plasm, we may expect to find three classes of effects:

a. Some cells will be destroyed, or so injured that they are incapable of forming viable zygotes.

b. Some cells will be injured, but will form zygotes which are capable of living, though variously imperfect or pathological.

c. Some cells will not be appreciably affected.

It will be seen that this situation parallels the effects of disease on adults. In the presence of some acute bacterial diseases, some will die, others will live but suffer injury, still others will escape unharmed. In the case of bacterial disease, there is little or no evidence

that the elimination has any effect beyond producing (selecting) a race capable of withstanding the disease, except in cases where there is a mixture of races, which respond differently to the influence. In the latter class of cases, the surviving type may be superior or inferior, judged by general standards, to that perishing. Dr. Pearl assumes, however, that the selective action of alcohol or other poisons on the germ cells is such as to eliminate all the weaker gametes, — those which under normal circumstances would produce the poorer class of the population. Consequently, if Classes *a* and *c* are large, the survivors (Class *c*) will really be the best gametes, — not improved in any way by the alcohol, but producing better zygotes on the average, because originally more vigorous. The infertile eggs represent the smaller, less viable elements of the ordinary chicken population.

In the guinea pig, on the other hand, while Class *a* is approximately as in the fowl, Class *b* includes practically all the survivors. Few cells escape some injury. Hence Dr. Stockard's results. Why should guinea pigs and fowls thus differ? We cannot say at present, but it is not surprising that the cells of such different creatures should differ in their resistance to poisons. Analogous differences can be observed in the *same species* (e.g., man), with regard to the poisons of *different* bacteria. In some diseases most or all of those affected perish, while the rest remain uninjured. In others, while some perish and some escape, large numbers are variously injured. As Pearl points out, the results will differ according to the dosage. If the amount of poison used is sufficient, *all* will fall in Class *a*; that is, there will be no offspring. Of course it may not always be possible to attain this result without killing the parents. Short

of this extreme, a certain number will fall in Class *a*, while the rest will be in Class *b*, all showing injury. Still diminishing the dose *in proportion to the power of resistance*, Class *c* will begin to appear, and become larger as the amount of poison used decreases. In birds, the high temperature and rapid metabolism doubtless favor the rapid elimination of alcohol; thus the dose, though apparently identical with that of the guinea pigs, is in effect less. It may well happen in some cases that when Class *b* is small and Class *c* large, the *statistical* results will show an actual improvement over the normal population, in spite of the fact that a certain number suffer injury.

Outstanding problems

10. If, as appears certain, alcohol thus discriminates against the weaker gametes in the fowl, what will be the effect on future generations? It all depends on the source of the relative weakness. Is it a matter of hereditary composition, or of differences of nourishment, dependent possibly on position? In the latter case there will be no permanent effect; in the former, the *average* of the later generations should at least in some degree maintain the observed superiority. Thus, by an extraordinary paradox, it would be possible to improve a breed of fowls by administering alcohol to one or more generations. Experiments are now in progress, designed to settle this question.

If the germinal difference is hereditary, we should expect a strongly heterozygous or cross-bred type to show the effects more distinctly than a homozygous one. In such a mixed type there might be many different sorts of gametes, which might respond differently to environmental influences.

11. We now return once more to our original question. There is no reason to suppose that alcoholism, *as*

Results vary with dose and power of resistance

such, is inherited; but alcohol may affect the germ cells in such a way as to produce *defectives of various kinds*, even when it does not injuriously affect the health of the parents. This injurious result may be carried through generations, though they have never touched alcohol. On the other hand, if the dose is less in proportion to the power of resistance, a large number of gametes may wholly escape injury, and these may be the strongest members of the gametic population. Professor Karl Pearson of London has published statistics which seem to indicate the absence of any inferiority in the offspring of a series of workingmen addicted to alcohol. Thus the practical results may be diametrically opposite, according to the ratio between the poison and the ability to resist it, and the way in which the poison operates. *A priori* considerations indicate what is possible, but actual experience is necessary to show what will happen in the case of any particular species or race, under any particular conditions.

Dr. Goddard's evidence, showing the association of alcoholism with nervous disorders or feeble-mindedness, no longer possesses quite the meaning he attached to it. It is indeed a symptom, but the guinea-pig experiments show that nervous defects are precisely those which result from the injury to the germ plasm by alcohol in a previous generation. Of course no one will claim that they are necessarily due to this cause, but in any given case it at least appears possible.

CHAPTER SEVENTEEN

NATURAL SELECTION

1. A FIRE, once lighted, burns in all directions until the fuel is exhausted. Life similarly extends, flowing into every possible channel until checked by circumstance. It is possible to imagine a universe which might become completely vitalized, alive in all its parts; but immediately it would produce non-living waste materials, as the result of its own activity. Burning or living are *states* which, from their nature, imply the coming and going of material; hence a house cannot be *all* on fire, or a person *all* alive. By the constant addition of fuel, the sacred flame can be kept burning indefinitely; by a similar process the flame of life *has* been kept burning these many million years. The *activity* has been continuous, the *materials* ever changing. **The extension of life**

2. When we speak of life seeking *opportunity* for extension, we need not imply anything more purposeful than the similar activity of the fire. Living beings feed, grow, and reproduce. These processes, unchecked, lead to increase in what is called geometrical progression, like compound interest. It is easy to calculate that any common roadside weed, occupying a square foot of ground and producing 500 seeds in a season, would in a few years cover the whole land surface of the earth with its offspring, if all survived. As a matter of fact it does nothing of the sort; most plants and animals are about as numerous one year as the next, the population remaining constant. Even when there is a rapid increase, as for example when the so-called Russian thistle reached this country, it is temporary, and does not go nearly to the theoretical limits. **Life everywhere checked**

Ratio between numbers and chance of survival

3. Why should life thus press against the environment, seeming ever to seek the impossible? In a certain sense, the hunger of life and the hunger of fire are parallel phenomena, as St. Francis seems to have dimly perceived when he regretted having deprived "brother fire" of the opportunity to consume his coat. There is, however, another point of view. Life cannot extend indefinitely; everywhere it finds limits to its activities. The 500 seeds of the roadside weed are so many trials, experiments, tickets in the great lottery of the world. It is practically impossible for *all* to succeed, and consequently, were no surplus produced, life would become extinct. By a strange paradox, it becomes necessary to accept failure in order to attain success. Sacrifice is part of the game, and those who fail have played their part. There is actually a definite ratio between the number of offspring and the chances of survival. The scale insect which produces a family of six thousand prospers as a species, but the individual at birth faces fearful odds. We recall the old story of the lion and the fox. The lioness goes forth with her single cub, and meets mother fox with her many children. "Ah," says the fox, "I have a fine family; I am sorry for you, with only a single cub!" The lioness replies: "I beg you to recall that *my* child is a lion, yours are only foxes!" Biologically, the lion is quite right. Species which produce few young are those in which the rate of survival is correspondingly high; one lion is worth several foxes, and thousands of spiders, in this sense. Nevertheless, even the most successful forms of life cannot avoid losses, and were man himself to produce on the average only two children for each pair of parents, our species would vanish from the earth.

The struggle for existence and the survival of the fittest

4. Since the process of elimination must go on, is it perfectly haphazard? Is the lottery altogether impartial? Surely not; we have only to think for a moment of the causes of premature death. Disease may not spare the best, from our point of view, but it picks and chooses in its own manner. Some deaths are due to what we call "pure accident," but the more we examine into the subject the smaller this accidental group appears to become. Creatures attacked by enemies may fight or fly, but they differ in their ability to do either. Individuals are not exactly alike, and consequently their chances of survival are not alike. After all, it is not Nature which chooses, if by "Nature" we mean an external, impersonal agency. Nature would be impartial, if the behavior of life were uniform. The process we have just described, which is going on everywhere and at all times, is what Darwin called *Natural Selection*. Its consequence is the *Survival of the Fittest*. The effort to survive is spoken of as the *Struggle for Existence*. These expressions are now classical, and cannot be changed; but they need a little explanation. The struggle for existence appears to imply volition, but this is not intended. There is volition in the effort to obtain food, or to fight enemies; but the defense of the body against the attacks of bacteria is quite unconscious. Plants, which we do not think of as being aware of things, struggle for existence as much as animals. Then, again, the survival of the fittest implies only *fitness to survive* under the given conditions. Ideal fitness has nothing to do with it. One who is fit to go through college may not be fit to resist smallpox or swim when thrown into the water. Moreover, the only fitness we are concerned with is that to produce offspring. Creatures may live to old age, yet remain

wholly unfit in the Darwinian sense; their *race* does not survive.

Natural selection compared with selection by man

5. The phenomena we have just described can be observed at any time; their existence does not admit of dispute. The question is, what have they to do with evolution? Is the race altered by the survival of the fittest? The whole matter turns on the question whether, since the survivors differ from those which perish, the differences will be transmitted to future generations. Darwin took this for granted, and was fortified by the experience of mankind in producing many special varieties of animals and plants through the agency of selection. In one sense, of course, man had not produced these things, he had only chosen them; but their selection and isolation, and often recombination, had in effect changed the character of the populations. Man had done this, as for instance with the sugar beet, in the course of a few years. Was it not reasonable to suppose that Nature could do the same, given almost unlimited time?

Modifications of Darwin's theory

6. Since Darwin's day our knowledge of the processes of heredity has greatly increased, and consequently the whole subject has had to be reconsidered. It is no just criticism of Darwin, that he did not introduce into his reasoning facts which were then unknown. First came Weismann, the eminent zoölogist of Freiburg in Baden, with his theory of the continuity of the germ plasm. He pointed out that each new generation arose from the special reproductive cells of the one before, and consequently the effects of environment on the organism could not be inherited. The only exceptions to this rule would be those in which the germ plasm itself was affected. This theory at first caused surprise, but cases brought forward to show the "inheritance of acquired

characters" broke down on examination. The characters, if acquired, were due at least in part to the hereditary constitution, and hence would be reproduced from the germ cells. Even if the inheritance of acquired characters sometimes occurred, it was certainly too rare to be important.

The process of natural selection of course knows nothing of these matters. The creature is selected on account of what it *is*, no matter how it became so. Thus a highly educated person of mediocre ability would have an advantage over an uneducated one who might be markedly superior from the standpoint of inheritance. If the principal characters of organisms were such as are not inherited, natural selection could do nothing for evolution; there would be no relation between fitness to survive and ability to leave fit offspring. Obviously, this is not true; but we can no longer assume that *all* sorts of variations tend to be inherited.

Limitations to the power of selection

7. The researches of Mendel, greatly extended and supplemented in later years, have shown that many individuals are *heterozygous* or cross-bred. These, though "selected," will not come "true." They break up into all sorts of new combinations. This is why eminent men do not usually have sons equal to themselves. Some types, such as the "blue" Andalusian fowl, are incapable of existing except as heterozygotes, and no process of selection will cause them to have more than half their offspring "blue." The other half will be blacks and speckled whites. Furthermore, selection cannot eliminate the recessives, — those determiners which may be present in the germ plasm of cross-bred individuals without producing any effect. Morgan, in working with flies, has found a number of "lethal" factors, which when received from both parents are

fatal to existence. The individuals homozygous for them never develop at all. No selection could be more rigorous than this, yet these factors have not been eliminated from the stream of inheritance. They survive in the heterozygotes.

The constancy of determiners

8. It also appears that although *individuals* are different, the *determiners* giving rise to them go on from age to age unaltered. That they never alter is of course an absurd proposition; but they are at any rate extraordinarily constant. "Original variations" modifying the very substance of the reproductive cells are decidedly rare, instead of occurring all the time, as was once supposed. The constancy of these elements is shown not merely by the experience of breeders, but also and more convincingly by the record of the rocks. Fossil remains millions of years old show us that certain forms of life, though continually subjected to "natural selection," have remained substantially unchanged. Even their habits have scarcely altered. Others, of course, have been greatly modified, but change seems not to have been obligatory as a consequence of the selective process.

Conservative and plastic types

9. All these considerations appear to weaken the theory of natural selection as an effective cause of evolution, but in reality they simply modify our idea of its manner of operation. Unquestionably some types are more "plastic" than others, and are more quickly molded by selective agencies. Those organisms whose life is very simple, who require "but little here below," do not quickly change. There is no direction in which they can readily improve. Bacteria, for example, have apparently existed for fifty million years, without important structural changes. Many species have developed, adapted to particular modes of life,

but the group as a whole has continued to carry on its lowly functions in its relatively simple way. On the other hand, the higher forms of life exhibit innumerable structural modifications, which adapt them to all sorts of special conditions. The effects of natural selection are in proportion to the necessities of the organism, in relation to the environment. If no change is advantageous, selection itself will destroy all variations, and hold the creature true to type. Thus it can just as well prevent evolution as cause it. But when conditions are changing, or new adaptations permit entrance into new fields of opportunity, selection is a powerful factor, provided that the necessary heritable variations occur. In the absence of such variations there may be no "fittest" to survive, and the species becomes extinct.

Complexity of living nature a result of selection

10. Regarding the matter quite broadly, there can be no doubt that the beauty and variety of living things has been brought about through the agency of selection. The rocks are full of fossil types which have perished; every species has had to endure the test of fitness. In a sense, the motive force of evolution has been environmental change, compelling adaptations as the price of existence. Without periods of heat and cold, moisture and dryness, without a world presenting all sorts of different conditions, evolution could not have taken place. Man is the outcome of innumerable trials, innumerable adjustments. As life has become more varied, each type has become part of the environment of others, — as their prey, or their enemy, or as occupying space they would possess. Thus the complexity of adjustment has increased by a principle of acceleration growing out of itself, like progress in human society. Whichever way we regard the matter, we can only come back to the great realities. What we see represents the

pick of the ages; for every species existing, thousands have perished, many before they had become well established. Over and over again, success has been won, only to be lost as times changed, and the old had to give way to the new.

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CHAPTER EIGHTEEN

ARGUMENTS FOR EVOLUTION

Obstacles to the understanding of evolutior

1. It is one thing to show how evolution might have occurred, and another to demonstrate it as a fact. Modern naturalists are more nearly unanimous about the demonstration than the theory. Practically without exception, they agree that the various forms of life have developed from common ancestors through an evolutionary process. When it comes to explaining *how* this happened, there is plenty of room for differences of opinion, owing to the complexity of the subject. There is no single cause, no simple explanation; and like the blind men of India who examined an elephant, scientific workers have magnified the importance of their particular points of contact. For example, it appears to be very difficult for the experimentalist to conceive of processes which cannot be demonstrated in the laboratory, changes requiring thousands of years. On the other hand, it is hard for the philosophical biologist, who sees things in the large, to realize the importance of little things. He will, as it were, draw large checks on the bank of Nature, not realizing that there may be obstacles to getting them cashed. This error was the prevailing one some years ago, but today the tendency is too much in the other direction. In our very proper zeal for tangible facts, we have lost some of the breadth of view and power of imagination which are necessary for scientific progress.

Uniformity of the essential laws of life

2. Since we agree as to the *fact* of evolution, we can all join in our search for the *evidences* of its occurrence. First of all, we note the extraordinary uniformity which underlies all the manifestations of life, animal or vegetable. Protoplasm is everywhere the living substance,

and the processes of heredity and variation are essentially the same in every case. We can actually reason from a plant to an animal, as the experimenters of recent years have so frequently shown. Professor Jennings, working with minute Protozoa in ditch water, can determine facts of the greatest importance for the understanding of mankind.

Then we have the fact that all life, so far as we know, comes from preëxisting life. How, when, or where life originated we do not know. It may have had more than one origin, but in any given case the presumption that a particular animal or plant did not arise by "spontaneous generation" is so strong that we take the fact for granted. In any event, it is impossible that any of the higher forms should thus originate.

Many organisms have similar tissues

3. Not only is there this general uniformity in life processes, but it is astonishing to note how few are the *kinds* of materials, or *tissues*, of which animals and plants are constructed. The voluntary muscle fibers of man, with their fine cross-lines like those on a file, look like those of a beetle. The nerve tissue, connective tissue, skin tissue, and so forth are substantially alike in great numbers of different animals. So again in plants, we find greenness always due to chlorophyll, and the building material stiffening the walls of the cells is cellulose.

Homology in organs or parts

Then again, throughout long series of diverse types, the *organs*, or working parts made of tissues, correspond accurately. They are said to exhibit *homology*. No one doubts that the eyes of a man, a dog, and a frog represent the same structures; although this is not true of the eyes of an insect or a mollusk. The arms of a man are homologous with the wings of a bird; it is an anatomical error, if a pleasing symbolism, to represent angels with arms and birdlike wings.

Why should all this uniformity of type exist amongst so much lesser diversity, except as a result of evolution from common ancestors? Agassiz used to say that it might represent not common descent, but common origin in the mind of a Creator. One may note the evolution of pottery in a large museum, and refer the modifications to their common source in the mind of man. The idea is a fascinating one, but no modern naturalist accepts it in place of evolution; though he may sometimes ask himself whether there has not been a creative influence guiding the evolutionary process.

Remnants of ancient structures

4. We can say of the similarity of structure just described that it is at any rate functionally appropriate. Whatever its origin, it serves the purposes of the creatures. There are, however, other similarities which may not be thus explained. We frequently find *vestigial* structures, which not only possess no function, but, as in the case of the human appendix vermiformis, may be actually detrimental. A little projection on the inwardly folded margin of the human ear appears to represent the tip of a pointed lobe which existed in an ancestor. The horse wrinkles the skin of its neck to drive away flies, using a muscle which exists in us only as a very thin and useless layer of tissue. We no longer cock our ears like a dog or a horse, but remnants of the muscles for this purpose remain, and some persons can use them to a certain extent.

Old characters visible in the embryo

5. Still more astonishing is the evidence from *embryology*. The human embryo, long before birth, exhibits structures on the side of the neck corresponding to the gill slits of early vertebrates. They are inexplicable except on the view that a remote ancestor was aquatic. The slits divide the gill arches, and it is from one of these that the lower jaw develops. Embryologists be-

lieve that had it not been for early aquatic life, we should not have possessed this useful structure. Man at birth is tailless, but the early embryo has a distinct pointed tail. So with many other structures, the principle applying to plants as well as animals. These facts have led to the saying that the *ontogeny* (individual development) repeats the *phylogeny* (race development or evolution). This is largely a fact, yet it has been exaggerated in some quarters, with grotesque results. It is not necessary, for instance, to assume that a boy must pass through a stage in which he is a howling barbarian.

Past life as revealed by fossils

6. Another class of evidence is derived from *Paleontology*, the study of fossils. Since the earliest known rocks (Cambrian) which contain well-preserved fossils show us a highly developed invertebrate fauna, it is impossible to trace the origin of the major invertebrate groups. In the case of the vertebrates we are more fortunate, and in several instances series of forms have been discovered, illustrating evolutionary progress. For an account of two of the best of these, see the chapter (pages 417 and 425) on the horse and the elephant. The geological record, in spite of the large collections obtained, remains extremely fragmentary. Thus, although we know the later (Tertiary) history of the mammals fairly well, their much longer Mesozoic evolution is represented only by the most meager fragments. There are innumerable "missing links" in all groups, and we can never hope to complete the history of life from fossil remains. At the same time, all we know accords with the theory of evolution, and every fresh discovery in some measure illustrates it. It must not be supposed that the several phyla have steadily progressed from lower (less complex) to higher (more

complex) throughout the ages. On the contrary, after an exuberant development in certain lines, it has often happened that some relatively primitive and insignificant type has given rise to the group destined to be dominant long after. This is so true, that we are accustomed to think of highly specialized types as ends of the branches of the tree of life, giving rise to nothing beyond. For example, though amphibians were derived from fishes, it was not from the highest fishes, such as the perch or sole, which have gone far beyond the point where it would be possible for them to develop any amphibian features. The paleontologist, convinced of the truth of evolution, is greedy for every fragment of evidence he can glean from the past. It is as though some great book had been broken up, and the leaves scattered far and wide. He knows that many of the leaves must have been destroyed, others are lost and will never be found; but every page, every line, which he can recover conveys part of the message of the book.

Distribution of life confirms the idea of evolution

7. The study of *geographical distribution* is also very suggestive. If evolution has taken place, members of a group having a relatively recent common ancestor might be expected to occupy the same continent or hemisphere. This is what we find in a number of cases; for example, the humming birds, with hundreds of species, are all American. There seems to be no climatic or other reason why humming birds should not flourish in the Old World tropics, but they have never been able to get there. A series of islands forming an archipelago will often have a series of birds, mice, reptiles, or snails, each island with its particular sorts. As Darwin noted in the case of the Galapagos Islands, the nearness of the islands, and the shallowness of the sea between them, correspond in a marked degree with the degree of re-

semblance between the native products. It is an obvious suggestion that some of the islands were more recently connected than others, and that evolution has been going on since they became separated. Such theories are beautifully illustrated by the animals of the Hawaiian Islands, and especially the remarkable snails (*Achatinellidæ*) characteristic of the group.

The exceptions to the principles just cited are quite numerous, but they can often be explained, and it is presumed that only our ignorance prevents the explanation of all. For example, the llama of South America belongs to the Camelidæ or camel family. That it should exist so far away from its relatives, the camels, seems quite anomalous, and contrary to the idea of descent from a common ancestor. The explanation is found in the presence of great numbers of camel fossils in North America; the camel group once extended all over the western hemisphere, as well as over Asia, but has now left only remnants at the ends of its range. The opossum, a marsupial, is far removed from its marsupial relatives in Australia; but we know that marsupials once existed in every continent and in great variety. The development of the higher mammals crowded them to the wall, and they now survive in a very small part of their former territory.

Changes in animals and plants under the comparatively brief influence of man

8. Darwin was influenced by the well-known fact that many domesticated animals and cultivated plants have changed greatly under the influence of man. The race horse and the dahlia, the pig and the plum, are no longer what they were a few centuries ago. Man has chosen what he wanted from among the variations afforded by Nature, and has preserved and propagated many beautiful and useful types. He has, when the fancy took him, developed the grotesque or even

hideous, and has saved among dogs and goldfish what Nature would surely have rejected. Some of the domesticated and cultivated varieties are so distinct that did we not know their origin, they might pass for new species, if not new genera. If man's selections, combined no doubt with more or less crossing in most groups, could produce such marked results within a short time, what might Nature do in millions of years? In later years, Professor de Vries of Holland has called attention to the phenomena of *mutation*, whereby a species of plant, such as Lamarck's evening primrose, may give rise to a series of distinct types which will breed true. We do not call these species, because we know their origin, yet some of them are as distinct as admitted species, and if found isolated would be regarded as such.

CHAPTER NINETEEN

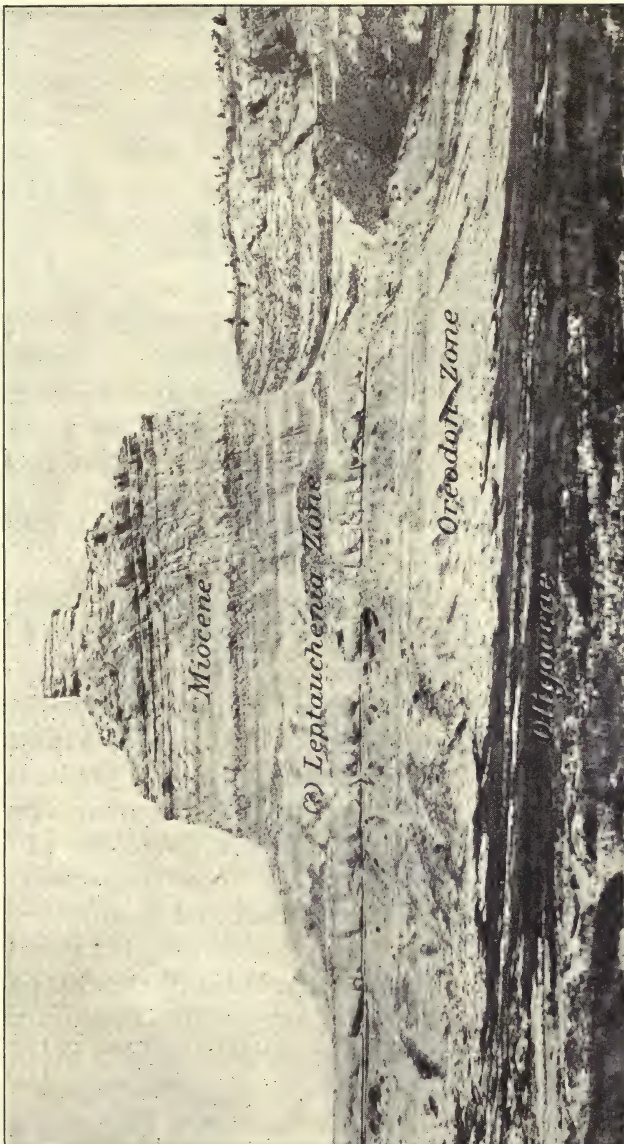
THE HISTORY OF LIFE

Absolute and relative age of fossils

1. It is well known that life has existed on the earth for many millions of years. The evidence for this is found in the fossil remains scattered through the sedimentary rocks. The *relative* age of nearly all the rock formations is known, since they have been found in various places one upon the other. Thus if in one locality *B* is above *A*, we know that it is later, except in the case of a complete overturn, which can occur only in a limited area. At another place we find *B* with a third formation *C* above it, though *A* may here be absent. We have, then, *A*, *B*, *C*, in proper sequence. Somewhere else *D* will be found over *C*, and so on, until we are able to construct a geological column, such as may be found in textbooks. Of course all the formations cannot be found actually forming such a column, if only because each new deposit is necessarily made up of materials derived from older ones. The *absolute* age of the rocks is very much more difficult to determine, but some estimates have been made from the consideration of various factors, such as the probable rates of deposition and denudation, and the changes taking place (at approximately known rates) in radioactive minerals.

Type fossils of different strata

2. The correctness of the method just described necessarily depends on our ability to recognize various formations when we find them. How are we to know that the *B* which lies beneath *C* is the same *B* which elsewhere rested above *A*? It is not likely to be continuous from one place to the other. The character of the rock itself is no certain guide; rocks of entirely different periods may present the same appearance and



From Osborn's "Age of Mammals"

FIG. 25. Scott's Bluff, in western Nebraska, showing the stratification of rocks of Tertiary age, containing different vertebrate fossils and representing a long period of time.

contain the same elements. The only decisive criterion is the presence of characteristic fossils. Thus the fossils enable us to recognize the formations, and the relative positions of the formations in turn give us relative dates for the fossils. What do we mean by characteristic fossils? Experience shows that throughout all the ages life has been changing. The various geological levels have their representative remains. The length of time a family, genus, or species may last varies greatly according to the type concerned; but whenever we can get an assemblage of species, the geological date becomes relatively exact. In a city, the names of a hundred persons present at a meeting would usually define the date within a year, although some of them might have lived there fifty years. The same principle applies to the fossils, though of course we are dealing with very large units of time.

Relative value to the geologist of different groups of animals

3. There are two qualities which make particular groups of fossils especially useful to the geologist. One is the likelihood of being preserved. Thus marine shells living in shallow water are especially important, since the shells are readily fossilized and exist in situations where they are likely to be covered by mud or sand and preserved. Consequently we find such shells in very many formations, and can compare the sets one with another. At the other extreme are butterflies, of which fewer than 25 species are known fossil, and none of these in more than one place. It is impossible, from such scanty remains, to form any exact idea of the changes in butterfly structure from age to age. The other valuable quality is that of showing relatively rapid modification. Thus the mammals have changed conspicuously during periods which have witnessed very little change in various types of trees. Other organisms are even

more constant than the trees. Not only this, but the mammals have progressed along definite lines, so that the different members of the horse group, for example, form a sequence which is readily appreciated. Given the key to this development, — increase in size, reduction in the number of toes, and so forth, — any one having the fossils before him could arrange them in the proper order. The oysters, on the other hand, have, as it were, shuffled their characteristics, producing a multitude of species without any distinct advance. Consequently, though the species of oysters are extremely useful for the recognition of geological horizons, the student could not arrange them correctly except by knowing whence they came.

Paleontology part of the science of life

4. The science of fossils is called "paleontology," literally, the science of that which is old. Paleozoölogy has to do with fossil animals, paleobotany or paleophytology with fossil plants. The student of these subjects is a paleontologist, though we also hear such strange expressions as "fossil botanist." Since fossils are of such fundamental importance for geology, paleontology has long been associated with that science as a division, and is so treated in textbooks. It is, however, obviously part of the study of life, and now that evolution is made the cornerstone of biology, the whole subject acquires new importance. To study the life of today and ignore that of the past is as unprofitable as to study a country or city without taking any account of its history.

The geologic time table

5. Dr. Charles Schuchert of Yale University has published a "Geologic Time Table" which, though not pretending to exactness, represents the most expert consideration of the available evidence. The time represented since the beginning of the Cambrian, where we first meet with satisfactory fossils, may have been

Geologic Time Table (Adapted, with alterations, from Schuchert and Barrell, *American Journal of Science*, 1914)

Eras	Major Divisions	Periods	Epochs	Advances in Life	Dominant Forms of Life
Modern*			Recent (Alluvial or Post-Glacial)	Rise of Civilization	Age of Man
Cenozoic (probably 3 to 4 million years)	Quaternary	Glacial	Pleistocene	Extinction of many Great Mammals	Age of modern Mammals and great development of Herbaceous Plants
	Tertiary	Late Tertiary	Pliocene	Evolution of Man	
			Miocene	Culmination of Mammals	
		Early Tertiary	Oligocene	Rise of Higher Mammals	
			Eocene	Vanishing of Archaic Mammals	
Mesozoic (probably at least 9 million years)	Late Mesozoic	Cretaceous	Lance	Extinction of Great Reptiles	Age of Reptiles
			Montanian Coloradian	Extreme specialization of Reptiles	
		Comanchian		Rise of higher Flowering Plants	
	Early Mesozoic	Jurassic		Rise of Birds and Flying Reptiles	
		Triassic		Rise of Dinosaurs	
Paleozoic (probably at least 18 million years)	Late Paleozoic	Permian		Rise of Land Vertebrates and Ammonites Diversification of Insects	Age of Amphibians
		Pennsylvanian		Rise of Primitive Reptiles and Insects †	
		Mississippian	Tennesseian	Rise of Ancient Sharks	
			Waverlian	Rise of Echinoderms	
	Middle Paleozoic	Devonian		Rise of Amphibians First known land plants	Age of Fishes
		Silurian		Rise of Lung-fishes and Scorpions	
	Early Paleozoic	Ordovician	Cincinnatian	Land Plants?	Age of Higher Invertebrates
			Champlainian	Corals, Armored Fishes	
			Canadian Ozarkian	Nautilus	
		Cambrian	Croixian	Shelled Animals	
				Dominance of Trilobites	
				First Marine Plants	
Late Proterozoic	Algonkian	Keweenawan			Age of Primitive Marine Invertebrates. Fossils almost unknown
		Animikian			
		Huronian		Oldest Known Fossils	
Early Proterozoic	Neo-Laurentian	Sudburian			
Archeozoic	Paleo-Laurentian	Kewatin			Fossils unknown. Unicellular plants and animals are believed to have existed
The Unrecoverable Beginning of Earth History					

* The modern era, called by Schuchert and Barrell *Psychozoic*, is not a true era comparable with the others, but ought in all reason to be considered part of the Cenozoic.

† The insects are so well developed in the Pennsylvanian, that their actual origin must be much earlier.

from 30 to 50 million years. The tendency is to increase rather than decrease the estimate. It is quite certain, however, that life existed for an immense period prior to the Cambrian, though only very inadequate remains have been discovered. The deficiency of fossils in the earlier (Algonkian) deposits may be largely due to the unsuitability of primitive types for preservation; but more especially to the fact (as it seems to be) that the early life existed in the sea, and the old shore lines are now buried beneath the oceans or far below the surface of the earth. Although great masses of Algonkian rock have been studied, they appear to represent old land and fresh-water surfaces, where only very primitive forms of plant life existed. These include algæ (water weeds of low type) and minute objects considered to be bacteria. Somewhere, some day, some happy naturalist will perhaps discover an old Algonkian shore deposit, with well-preserved animals much older than any now known.

Life in Cambrian times

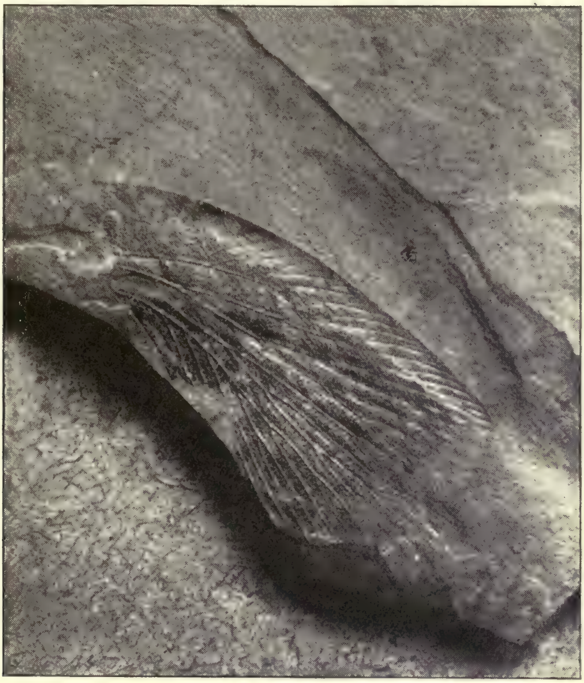
6. For our knowledge of Cambrian life we are especially indebted to Dr. Charles D. Walcott of the Smithsonian Institution. Cambria is the old name of Wales, where the Cambrian rocks were first described by the English geologist, Adam Sedgwick; but we now know them from many different regions. The most remarkable deposit of fossils was found by Dr. Walcott on the mountain side above Field, in the Canadian Rockies. Fragments picked up near the base of Mount Wapta indicated that somewhere on the slope fossils would be found in place. Following this clew, a quarry was made at an altitude of 8000 feet above sea level, and after the surface rock had been blasted out, a wonderful series of remains was obtained. So perfect is the preservation, that even such delicate objects as jelly-

fish have left recognizable impressions. There are many marine invertebrates, including highly organized crustacea of numerous kinds, but no vertebrates of any kind, and none of the higher plants. Worms were numerous, and some of them possessed remarkable characters, — leglike appendages, bristles, or spines.

Appearance of the vertebrates

7. After some millions of years a vertebrate fauna appeared, — still aquatic, but apparently living in fresh waters. Singular armored forms are found, apparently the ancestors of the fishes. Their exceedingly fragmentary remains occur in Colorado and Wyoming, in rocks of Ordovician age. The Cambrian and Ordovician constitute the early Paleozoic. In the Middle Paleozoic (Silurian and Devonian rocks) great changes are observed. The fishes now become abundant; land plants and arthropods (scorpions) appear. Finally, vertebrates become adapted to a partly terrestrial life, and amphibians are developed. We now come to the Late Paleozoic, often called Carboniferous, — that is, coal-bearing. It is divided into Mississippian, Pennsylvanian, and Permian, all periods of long duration. In the Pennsylvanian the great forests and masses of vegetation gave rise to anthracite coal, but flowering plants were absent. Land vertebrates were becoming numerous, and insects swarmed everywhere. The earliest insects were some of them of immense size; one found in France was about 2 feet 4 inches from wing tip to wing tip. These lasted for a long time, but in middle Pennsylvanian they died out, and the country was overrun with cockroaches, almost to the exclusion of other insect types. In the Permian, however, the land surface in North America was elevated, the climate became cooler, many new families of smaller insects developed, and the cockroaches diminished greatly in numbers and

importance. Here we come to the end of the Paleozoic, or period of the old life, as we choose to call it. In



From Proceedings U. S. National Museum

FIG. 26. Wing of fossil cockroach (*Phoberoblatta reticulata*) from the Carboniferous (Pennsylvanian) rocks near Brookville, Pennsylvania. Magnified about two diameters.

reality it was the young life, the youth of the world, and we are the real veterans.

8. The Mesozoic (middle life) period is called the age of reptiles. It may have lasted about nine million years, certainly not more than half the length of the Paleozoic. It begins with the Triassic and ends with the Cretaceous, — the latter name from *creta*, chalk, because it is the period of the chalk cliffs of Albion. Early in the

The age of reptiles

Mesozoic those strange reptiles known as dinosaurs became prominent, and this type continued to develop, producing carnivorous and herbivorous species, many of them of immense size. One of the best-known dinosaurs is the *Diplodocus*, of which a skeleton may be seen in the museum at Pittsburgh. The tail and neck are both very long, and the head is so small as to be inconspicuous. Many dinosaur skeletons are exhibited in the American Museum in New York and in the National Museum at Washington. Some were protected by massive bony armor plates, crests, or spines. All, however, had small brains, and they must have been stupid animals. For millions of years they flourished, but finally died out completely at the end of the Mesozoic. What destroyed them, we do not know; they may have been short of food, or perhaps the mammals learned to eat their eggs, which they did not know how to protect.

Advent of warm-blooded animals

9. While the dinosaurs were rulers of the earth, many important events were taking place. Warm-blooded creatures evolved from reptilian types, one series developing wings and becoming birds, the other retaining the four walking legs and giving rise to the mammals. The early birds, like their reptilian ancestors, were toothed. Of the first mammals we know little; but they were small, and are believed to have laid eggs, like the Australian duckbill of the present time.

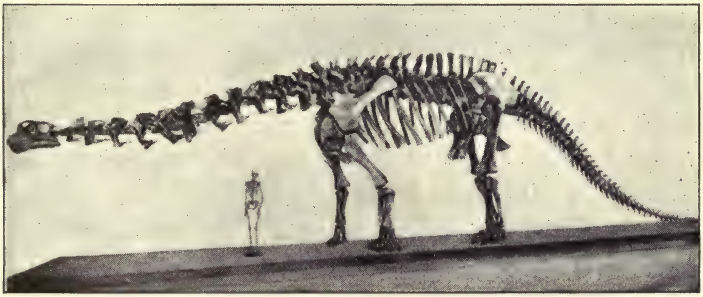
Flowering plants

Another event of scarcely less importance was the appearance of flowering plants, and with them of types of insects adapted for visiting flowers. The latter appear to have come in principally with the development of herbaceous vegetation at the end of the Mesozoic and during the Cenozoic. The first flowering plants were woody, and were mostly, if not wholly, pollinated through the agency of the wind, or at any rate without

Photograph from Am. Mus. Natural History

FIG. 27. *Brontosaurus* (or *Apatosaurus*), one of the dinosaurs, a gigantic Mesozoic reptile, as restored by C. R. Knight under the direction of Professor Osborn at the American Museum of Natural History, New York.

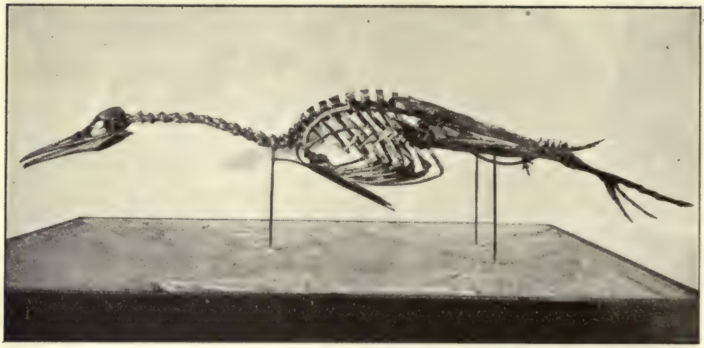
the assistance of bees or butterflies. Owing to the change in the flora, the landscape during the Cretaceous



Photograph from Am. Mus. Natural History

FIG. 28. Skeleton of *Brontosaurus*, with human skeleton for comparison.

must have been very different from that of the early Mesozoic. In the Cretaceous, the plants and most of the invertebrates, could we see them alive today, would



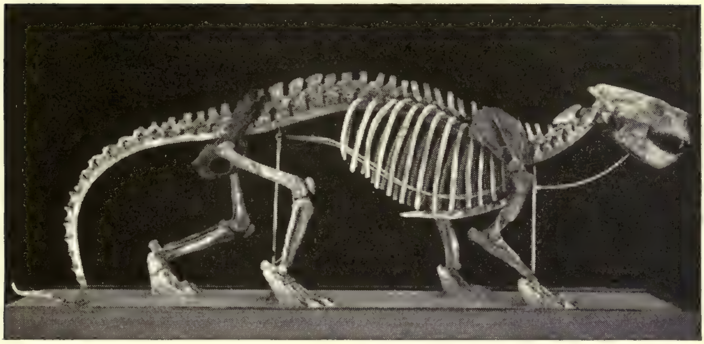
Photograph from Am. Mus. Natural History

FIG. 29. Skeleton of *Hesperornis*, a Mesozoic bird.

look familiar; but the vertebrate life would appear wholly strange.

The age of mammals

10. Following the Cretaceous is the Cenozoic, more often called Tertiary, — the age of mammals. This occupied three or four millions of years only, but it saw the development of the strictly modern fauna and flora. The mammals, which had remained insignificant and apparently not very numerous for millions of years, got a new start. Before very long they produced such an array of new types that we wonder where these could have been developing. Undoubtedly, both in the case of the mammals early in the Tertiary and the flowering plants in the Mesozoic, the apparently sudden exuberance of development must be partly illusory. Preparations for these brilliant displays on the stages of Europe and America must have been going on behind the scenes, — that is to say, in parts of the world whence we have no fossils of the periods concerned. Some day new light will be thrown on these matters, — perhaps in the far north, or in that great Antarctic continent which, though now covered with ice, once supported luxuriant vegetation.



Photograph from Am. Mus. Natural History

FIG. 30. Skeleton of *Patriofelis ferox*, Marsh. A large carnivorous creodont mammal from the lower Tertiary (Bridger Eocene) of western North America.

Photograph from Am. Mus. Natural History

FIG. 31. *Patriofelis ferox*, as restored by C. R. Knight. The creodonts, in later periods, gave place to the modern carnivores, the very numerous creodont genera becoming extinct.

11. In some respects the Miocene divisions of the Tertiary, say about a million years ago, saw the culmination of life in the northern hemisphere. The climate **The Miocene Period**

was mild, and the number of species of plants and animals existing was immense. The flora had become varied enough to permit innumerable adaptive modifications in the insect world, — species living on particular parts of particular plants. Life had flowed into almost every channel of opportunity. Then at the end of the Tertiary, during a relatively short period which we separate as the Quaternary, came a succession of glacial epochs, covering the northern regions with ice. The consequent impoverishment of the biota has not been wholly recovered from to this day. Nevertheless, in the presence of hard times, and doubtless partly in consequence of them, man developed. Here was a being who could in a measure defy nature; who could up to a certain point create his own environment and consequently take possession of the earth. The age of man ought to be regarded as part of the Tertiary, but this egotistical creature must needs set it apart, recognizing a grand division of geological time since he arrived.

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CHAPTER TWENTY

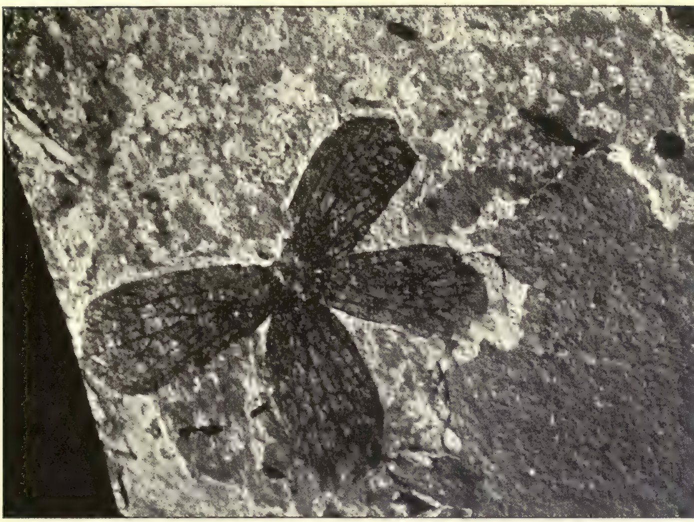
THE FLORISSANT SHALES OF COLORADO

1. NEAR the western base of Pike's Peak, almost under the shadow of that great mountain, lies the Florissant Valley. It is an upland region, over 8000 feet above the level of the sea, with grassy meadows and rocky slopes, and granite hills all around. Superficially it resembles many of the smaller so-called parks of Colorado, and there is little about it to attract attention. It is, nevertheless, one of the classic localities of the world, known to geologists and paleontologists everywhere, mentioned in all geological textbooks, — though, like a prophet in his own country, unheard of by most of the people of Colorado. Here may be found preserved the life of a million years ago: leaves and flowers, butterflies and beetles, in many cases almost as perfect as when alive, so that the most minute structures can be seen with the aid of a microscope. **The Florissant Valley**

2. During the Miocene Period, long before the appearance of man in the world, there was a large lake, shaped rather like the letter L, at what is now Florissant. In those days it is probable that the elevation was less than 8000 feet; possibly much less, since we know that the Rocky Mountains have been steadily rising during the last few millions of years. Whether they are still going up, we cannot tell, as any slight difference from year to year would be too small for us to measure, in the absence of any visible stationary point for comparison. The climate was moister and warmer, more like that of the Southern states today, but not tropical. This we know from the character of the vegetation. Around the lake were active volcanoes, which sometimes threw out very finely divided ash, sometimes liquid **The ancient Florissant lake**

The Miocene volcanoes mud or lava. At times of eruption there were, no doubt, violent gusts of wind and poisonous gases, while hot cinders fell here and there and set fire to the forests. Thus leaves and even branches were torn from the trees, and charcoal may still be found to testify to the forest fires. Insects and other creatures were killed, and fell into the shallow water of the lake, where they were presently covered by deposits of the finest ash, falling gently from above. Thus the various remains were hidden beneath successive layers of volcanic material, and when a mass of lava flowed over the whole, its weight pressed the wet ash down, and in course of time converted it into hard shale. What had been the life of the locality, now crushed flat, was hermetically sealed between the layers, to be uncovered in about a million years by creatures of a kind not then in existence. Little could the stray butterfly, perishing miserably, realize that some day its remains would be placed in a museum, where they would be the wonder and admiration of many generations of men!

How the fossils occur 3. In the course of ages the volcanoes ceased their activities, and movements of the earth drained the lake. The climate became much cooler and drier, and the fauna and flora changed accordingly. Whatever descendants of the old Florissant plants and animals might exist mostly migrated to quite other parts of the country, though some doubtless still live in Colorado. For example, the narrow-leafed cottonwood of the foothill gulches is so similar to that common in the Florissant shales, that we can hardly doubt that the former has been derived from the latter. Streams running through the valley bottom cut into the soft shale, and enormous quantities of it were carried away to the rivers of the plains and perhaps even to the sea. What precious

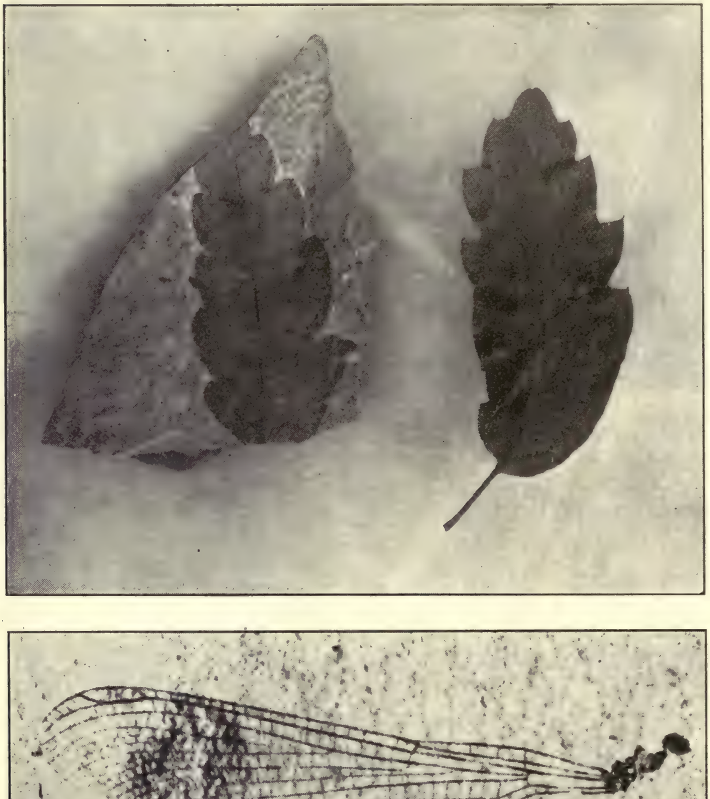


Photograph from American Museum Journal

FIG. 32. Fossil flower (*Porana cockerelli*, Knowlton) from the Miocene shales of Florissant. Enlarged.

fossils were thus destroyed, we can never know, but the amount of fossiliferous material still remaining is very great. At various places along the sides of the valley the shale is either exposed, or is readily reached by digging. On the surface it is usually weathered and spoiled; but by digging a trench good shale may often be found, and when carefully split by hitting the edge with a knife, it will show broad surfaces which may or may not reveal fossil remains. Collecting fossils in this way is laborious and often disappointing, but sometimes a single stroke of the butcher knife shows a specimen which carries back the history of some group of plants or animals a million years. After many days of work, the collections always prove to contain species new to science, and there are few localities which yield such good returns.

4. When the various fossils have been assembled together and studied, many interesting facts appear. We learn that the distribution of living things today is



From American Naturalist

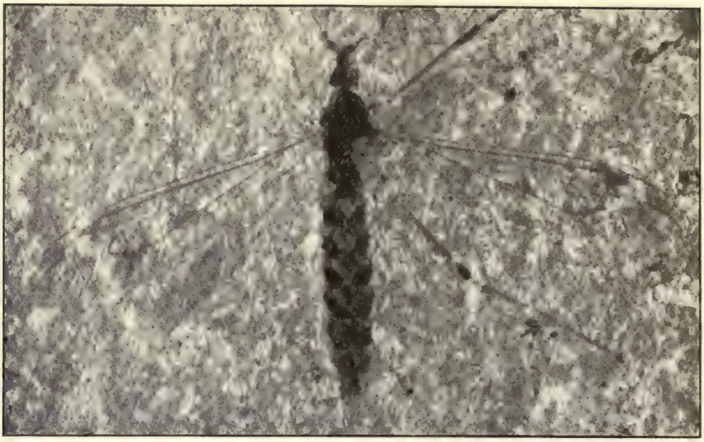
FIG. 33. Fossils from Florissant. Above, a fossil oak leaf, *Quercus ramaleyi*, and next to it a living representative, *Quercus fendleri*, which grows today in Colorado. Below, a wing of an extinct dragon fly, *Phenacolestes mirandus*. Enlarged.

The migration and extermination of plants

in many respects very unlike that of the past. In the shale are remains of redwood trees; and there are even great redwood trunks, now completely silicified, standing at Florissant. Today the redwood, once widely spread over the northern hemisphere, is making its last stand, confined to a rather small area in California. In the shale is also the *Ailanthus* or Tree of Heaven, a genus now confined to eastern Asia. We find in addition leaves of magnolia, elm, beech, chestnut, poplars, pines, and oaks, — such an assemblage as does not exist in the Rocky Mountains today. We are reminded rather of the mixed hardwood forests of the Eastern and Southern states. We wonder why some of these trees have disappeared from Colorado; why there are no longer any elms or chestnuts native in the region, though they still exist in the Eastern states. Was it the change of climate, or did some blight sweep them off, like the chestnut blight which is now so destructive along the Atlantic seaboard? There were figs and walnuts, — we have fruit of both; wine grapes and holly, roses of four different kinds, and many other plants dear to the eye or lips of man; but there were no men to see or use them. These things must seem strange to those who imagine that the beauty and wealth of nature exists for us alone!

The fossil tsetse fly

5. In Africa are found certain blood-sucking flies which carry the parasites of disease to men and animals. These are the tsetse flies (*Glossina*), and one of them is the bearer of the cause of sleeping sickness, which has wiped whole villages of people off the map. Another makes it almost impossible to keep cattle in certain localities. Many remarkable animals which once lived in North America are now extinct, and it is often very difficult to imagine the cause of their disappear-



Photograph from Am. Mus. Natural History

FIG. 34. *Tipula maclurei*, a crane-fly fossil in the Miocene shales of Florissant, showing the details of the markings of body and wings, as they appeared in life. Enlarged.

ance. Among suggested causes, disease often appears probable, and if insects existed which would be likely to carry the parasites of epidemic diseases, the probability is increased. It was therefore very interesting to discover, several years ago, a fossil tsetse fly in the Florissant shales. Since then others have been found, so that today we know four species of fossil *Glossina* from this locality. They may have been the cause of the extinction of some of the Miocene animals, but why did they themselves finally disappear, remaining only to plague the men and beasts of Africa? To this question we have as yet no answer.

Geography of ancient times

6. The Florissant fossils may throw light on events happening in very different parts of the world. During Tertiary time there was a long period when the present Isthmus of Panama was under water. We know this from the marine fossils found in cutting the canal, and

from the close resemblance between the marine fishes of the Atlantic and Pacific coasts at the present time. Also during Tertiary time was a period when what is now Bering Strait was dry land, and animals were able to cross from Asia to America, and vice versa. What can these remote happenings have to do with Florissant? When Bering Strait was passable, there was a migration of Old World animals into North America; we call it the Miocene migration. So again, later than this, the Panama region was elevated and South American forms were able to pass into Central and North America. With the first invasion came, for instance, the elephant group; with the second, the sloths. Now, so far as we can judge, Florissant shows very distinct evidence of the beginnings of the first invasion, but none of the second. If we are right in this, it follows that the Florissant shale was laid down in the interval between the arrival during the Miocene of Asiatic animals, and that later on of South American ones. By putting together various bits of evidence of this sort, we may eventually obtain a relatively exact chronology of the various deposits, and therefore types of life, which are represented in the country. The actual number of years represented is of course uncertain, but the *order* in which the events occurred, and the nature of the geographical and climatic changes, may be revealed to us. Thus apparently insignificant fossils, which at first seem to possess no general interest, may be the indicators of the acts into which the great drama of the earth is divided.

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CHAPTER TWENTY-ONE

CAROLUS LINNÆUS

Great men and their environment

1. THERE are some who maintain that great men are purely the product of their environment; that they are made by opportunity, and always arise out of a normal population to meet a need. Biology lends no support to such opinions; nor does history, which abounds with situations in which disaster resulted from incapacity. On the other hand, both biology and history show that capacity is sterile without opportunity, that the meeting ground of these factors is the place where significant progress arises. So it happened to Linnæus, that being a genius, he came into the world at a time when it was possible to apply his powers to fundamental reforms in natural history. In the eighteenth century, underneath a great deal of superficial slowness and stupidity, the ideas which we still regard as modern were developing and coming to the surface. Their expression was often crude, as in the political and social excesses of the French Revolution, the educational fantasies of Rousseau. The liberators of America, with their doctrine of the equality of men, were in some respects ill-informed,

FIG. 35. Carolus Linnæus.

were experimenting with materials they did not fully understand, but they were none the less prophets of the dawn. History has much to say about all these movements, but takes little note of the corresponding unrest in purely intellectual fields, where changes no less significant for the future were taking place.

Boyhood of Linnæus

2. Carolus Linnæus, also known as Carl von Linné, was born at Stenbrohult, in Sweden, on May 23, 1707. His father was a country pastor, who had an orchard and a garden. Carl grew up in the midst of flowers, and early developed that love of nature, of the beauty and variety of the out-of-doors, which was the motive power of his life's activities. His father naturally wished him to become a pastor, and sent him to a school at Wexiö, where he studied Latin and Hebrew under Lutheran auspices. Here he appeared to make little progress, and the school authorities were disposed to advise his withdrawal. They did not believe it was in him to make a competent clergyman; he had better occupy himself with some trade or handicraft. Pastor Linnæus accordingly went to Wexiö to remove his boy, full of sorrow for the failure. Here he had occasion to consult a physician, Dr. Rothmann, who was also a lecturer in the school. The doctor had taken note of Carl and was by no means of the opinion that he was a dullard. True, he would scarcely make a pastor; but he had scientific instincts, so why not a physician? So confident was Dr. Rothmann of Carl's abilities, that he proposed to take him into his own house for a year, and instructed him free of charge. The good doctor, acting out of the kindness of his heart and his zeal for the promotion of science, had no idea of the tremendous importance of his act.

Linnæus with Dr. Stobæus

3. The year with Dr. Rothmann completed, Carl proceeded to the University of Lund, where he found lodging under the roof of Dr. Stobæus. His new patron was a man of some consequence, with a collection of natural history specimens and a valuable library. The library was so valuable, containing so many rare and costly books, that it was kept locked; only Stobæus himself and his assistant had access to it. Carl Linnæus, eager for botanical knowledge, persuaded the assistant to bring him books, on the one condition that they should be read during the hours of the night, when there was no fear of detection. Very early in the morning they were replaced on the shelves, and the doctor had no reason to suspect the infringement of his rules. It so happened, however, that the doctor's old mother did not sleep well, and from her window she noted, night after night, a candlelight in the young man's room. Dr. Stobæus, suspecting some dissipation, resolved to find out what this meant, and at two in the morning softly went to Linnæus's door, and opened it. He saw Carl hard at work, the most precious botanical works from the library spread out before him! The doctor, far from being angry, was delighted to witness such zeal, and from that time did everything in his power to further Linnæus's studies. He gave him a key to the library, and begged him to read by day and take the necessary rest at night.

Life at University of Upsala

4. After a year at Lund, Linnæus wished to go to the greater University at Upsala, where he had hoped to find still better opportunities for learning. His parents consented, but were unable to support him there; he would have to work his way through as best he could. A year had not passed when he found himself almost penniless, — so poor that he had to line his shoes with

birch bark and pasteboard, and his clothes were worse than shabby. Nevertheless, he continued the study of botany with enthusiasm, and was once describing some plants in the botanic garden when an eminent professor of the University, Celsius by name, passed by. Celsius questioned Linnæus, and was so impressed by his knowledge of plants that he took him into his house and became his enthusiastic patron. Through this new influence the poor student became prosperous, and was even permitted to give lectures on botany, taking the fees of those who chose to attend. In many European universities the *privat docent* system is maintained; certain men, after due examination, are permitted to lecture, though not professors. If they are successful, they may have very large classes, and receive more in fees than the salary of a regular member of the faculty. So it happened with Linnæus, that he drew students from the established department of botany, and it seemed as though the tail were about to wag the dog. This aroused jealousy and indignation, and a rule was passed that henceforth no undergraduate should be permitted to give public lectures. This cut off Linnæus's source of income, but he was now ready for other enterprises.

Botanical explorations in Lapland

5. The Academy of Sciences at Upsala requested Linnæus to make a journey to Lapland, to collect and study the products of that country. We have his narrative, showing the enthusiastic spirit in which he set forth:

"I journeyed from Upsala town the 12th of May, 1732, which was a Friday, 11 o'clock A.M., when I was 25 years old, all but twelve hours. Now began all the ground to delight and smile, now comes beautiful Flora and sleeps with Phœbus. . . . Now stood forth the

winter rye quarter of an ell tall, and the grain had newly shown a blade. The birch began now to burst forth, and all leafy trees to show their leaves, except the elm and aspen. . . . The lark sang to us the whole way, quivering in the air. . . . The sky was clear and warm, the west wind cooled with a pleasant breeze, and a dark hue from the west began to cover the sky. . . . The woods began to increase more and more, the sweet lark which ere now had delighted our ears, deserted us, but yet another one meets us in the woods with as great a compliment, namely the thrush, Turdus minor, who, when she on the highest fir-top plays to her dearest, also lets us joy therein. Yes, she tunes in so high with her varied notes that she often overmasters the nightingale, the master of song."

In the autumn he returned, after a journey of about 2500 miles, mostly on foot and alone. The *Flora Lapponica*, published later, gave an account of the plants he found. One of these was the delicate and beautiful twinflower, which afterwards came to bear his name and was called *Linnæa borealis*. It was the wish of Linnæus that he should be commemorated by some lowly and humble plant of his own northern country, rather than by a gorgeous product of the tropics.

Journey to Holland and other countries

6. Linnæus now turned to teaching, and later to medicine, as a means of earning his living. After a time he made a journey to the principal countries of Europe — to England and France, Germany, and Holland, — in order to visit the botanical establishments and meet the botanists. Many stories are told of what he saw and did on this eventful journey. At Leyden in Holland there lived a famous old aristocrat named Boerhaave, equally celebrated in medicine and botany. Linnæus, provided with a suitable letter of introduction,

called on him every day for a week, but was not admitted. It was said that Boerhaave had made even Peter the Great of Russia wait two hours in an anteroom before seeing him. There seemed no chance for the young botanist, but it occurred to him to send in a little book he had published. This pleased Boerhaave, who at last granted him an interview, and took him into the garden to see a tree which was supposed to be undescribed. Linnæus at once recognized it, and told his learned host where he would find a description; when they returned to the house the book was found, and Boerhaave had to admit that he was right. In such ways Linnæus gained the friendship and respect of men in the countries he visited, and came away with the beginning of an international reputation.

Professor at Upsala

7. After practicing medicine in Stockholm with great success, Linnæus at length became Professor of Botany at Upsala. This enabled him to devote himself to biological science, and to the encouragement of those who were interested in natural history. His influence was profound, both through his published works and his personal relationships with students all over the world. In North and South America, in China and Africa, wherever explorers could penetrate, Linnæus had his friends and disciples, collecting plants and animals for their beloved master. Some of these helpers are still remembered in the names of familiar plants; thus Peter Kalm sent from North America the beautiful genus *Kalmia*, the so-called laurel of our Eastern states.

The Linnæan classification of plants

8. The work of Linnæus was extensive and varied, but we are now concerned only with its principal aspects. In the field of botany he devised a system of classification which was based primarily on the number and character of pistils and stamens. Those who had

previously given attention to the structure of flowers had interested themselves in the conspicuous parts, the brightly colored petals. Linnæus realized that the essential organs were those which produced the ovules and pollen, the means of reproduction. The new conception justified itself in various ways; it appeared to bring together related but superficially dissimilar plants, and to solve many puzzles. It was also very easy to understand, and the merest beginner, with the Linnæan system, could classify plants with fair success. Today we classify plants on a different basis, not because we deny the importance of the reproductive parts, but because we now see that *all* parts are more or less important and must be considered. The idea of evolution leads us to the conception that there is such a thing as a *natural classification*, in which the arrangement is expressive of actual degrees and kinds of relationship. This natural classification is an ideal to which we constantly approach, but which we never can expect fully to realize; hence botanical (and zoölogical) arrangements are constantly subject to change, and no simple method, however convenient, can be accepted. We have abandoned the beautifully simple and intelligible Linnæan method for one far more intricate and difficult, compelled to do so by the change in our scientific ideals.

The Linnæan system of naming animals and plants

9. The other great contribution to scientific reform made by Linnæus has to do with names. He was the founder of modern zoölogical and botanical *nomenclature*. The language of science was Latin, the names of animals and plants were Latin, and even those of men who wrote on these subjects took a Latin form. Previous authors had the conception of the *genus*, the group of kinds or *species*, to which was given a distinc-

tive name, preferably derived from classical sources. Thus, all violets were *Viola*, all slugs *Limax*. To these designations were added sentences defining the different sorts belonging to these genera. Lister, writing in 1678, called the common large garden slug *Limax cinereus, maximus, striatus et maculatus*, which simply means the large gray streaked and spotted slug. In Europe any one at all familiar with slugs would at once recognize the animal, so that the name, if cumbersome, was sufficiently illuminating. It was a name and description all in one. At the time of Linnæus many new animals and plants were being discovered and described; strange creatures were coming from all parts of the world, and it was obviously impossible to find a sufficiently illuminating sentence-name to designate each. The method was too cumbersome and too difficult. Therefore Linnæus proposed a new plan, — to retain the genus-name, and add to it a single other word, designating the species. The large slug accordingly became *Limax maximus;* the sweet violet, *Viola odorata;* the horse, *Equus caballus;* and mankind himself, *Homo sapiens* (*sapiens*, wise or knowing). But if the sentence were no longer sufficient to indicate the species clearly, how should the single word suffice? It did not, but when it was first published, it was to be accompanied either by a description or a reference to some previous author who had given a description or figure. The validity and meaning of the name had to depend on the adequacy of the accompanying data. At the same time, specimens of the species named were to be preserved whenever possible, and would be useful thereafter as evidence. Such specimens we now call *types*, and regard them as among the most precious possessions of any museum.

The *Species Plantarum* and the *Systema Naturæ*

10. The rapid and wide acceptance of the Linnæan system of nomenclature was due partly to its inherent simplicity and convenience, but also to the fact that Linnæus himself proceeded to apply it to all animals and plants known in his day. He cataloged the living creatures of the world, so far as they had been recorded or were represented by obtainable specimens, and to every species applied a name. In the *Species Plantarum* of 1753 we find the starting point for botanical nomenclature, while the tenth edition of *Systema Naturæ*, published in 1758, gives us the earliest animal names now entitled to recognition. After the name, for purposes of reference, we often write the name of the author who first proposed it. Such author-names, when frequently cited, are usually abbreviated, and by common consent "L." stands for Linnæus. Consequently, in looking over any catalog of the animals or plants of a country, one may see at a glance how many and which were known in Linnæan days; they are those the names of which are followed by the letter "L."

Modification of Linnæan system of nomenclature

11. Linnæus sometimes added a third name, to designate the variety. Thus European man was *Homo sapiens Europæus*. In later times much more interest has been taken in variations and local races, so that the use of varietal or subspecific names has become general. The various complexities thus arising are chiefly of interest to specialists, whose work demands the consideration of many small matters. Thus Forel, a Swiss student of ants, described an ant from British Columbia as *Formica rufa obscuripes whymperi*. This seems like a return to the old sentence method, but the meaning is quite different. *Formica rufa* is the red ant; in one part of its range it is represented by a race or subspecies which Forel called *obscuripes* (dull or dusky-

legged), and included in this race is a variety or lesser group, called *whymperi* after the well-known climber of mountains who discovered it. Most people, of course, would be satisfied to call the animal *Formica rufa*, but the more intricate investigations of Forel and others are very important as throwing light on problems of evolution, and the nomenclature has to meet the requirements of the work.

The question may be asked, how far should the naming of things go? Will not science be smothered by the mass of verbiage? The answer must be, that names are only means to the end of designating the objects with which we are concerned. The question is, then, how far is it worth while to go in separating out and distinguishing natural objects? Every individual of *Homo sapiens* has a name, and no inconvenience results. An infinite intelligence might be able to know and name every individual insect or bacillus, but the human mind has its limits. To the scientific man, however, the question is not so much one of ability to discriminate, as of ability to derive any general ideas or broad principles from the analysis. The work which seems to an outsider hopelessly petty and trivial may reveal the hidden forces of the universe, or may afford means of dealing with the most pressing problems of mankind. The individual naturalist does not usually expect to attain any far-reaching results, but he knows that he is contributing to a structure of knowledge, which when reasonably complete will begin to yield fruits of a kind he may only dimly foresee. His faith is, that the building will be serviceable, and all human experience goes to justify it.

12. After the death of Linnæus, writers in all countries continued to describe "new genera" and "new

Synonyms and homonyms

species." These were, of course, new only in the sense of not having been scientifically named before. It soon appeared that through various misunderstandings, or mere ignorance of what had been done, the same animals or plants often received several names. The rule of *priority* was accordingly established, and according to it the name first given, accompanied by data for recognition, is the valid or proper name. All others are *synonyms*, and have no standing. Names being of course international, it makes no difference where or by whom the first name is published, provided it is in Latinized form (and great latitude is permitted here!) and conforms to the rules generally. There is one necessary exception to priority, however: it cannot be permitted for two different genera of animals or of plants to have the same name, nor for two species in the same genus to be named alike. When names are thus inadvertently duplicated, the one latest published is called a *homonym*, and it is necessary to propose a substitute for it.

CHAPTER TWENTY-TWO

THE PRINCIPLES OF CLASSIFICATION

Necessity for classification

1. WHEN we contemplate the enormous bulk of scientific literature, and the multitude of facts discovered and recorded by scientific men, it seems as if science must eventually be smothered by its own mass. Yet those who have long engaged in scientific pursuits know that, on the contrary, it is becoming easier to deal with the accumulating materials. The secret of this is *classification*, the putting in order of our data so that each item can be found where it belongs. This is not peculiar to science. Although there are hundreds of millions of people in the world, a letter mailed in the Philippine Islands reaches a particular individual in Colorado, requiring only five words on the envelope in addition to the name. The reader of these lines has a name, and presumably lives in a particular house, on a particular street, in a particular town, situated in a particular county of a particular state of the United States. All these things being known and named, that individual can be found without any difficulty. So it is with the zoölogical or botanical classification. The reader is probably an American, he is a member of the species *Homo sapiens*, which is included in genus *Homo*, which falls in the family Hominidæ, which belongs to the Mammalia, these in turn being Vertebrata, which are Animalia or animals.

Significance of characters

2. Suppose for a moment that some being from another world has come here and captured a man. He is acquainted with zoölogical methods, and desires to find out what the strange creature may be. His reasoning will be somewhat as follows: Obviously, at the outset, this is an animal, not a plant. It has a vertebral

column, or so-called backbone (really a multitude of bones); so it is a Vertebrate animal. It is warm-blooded; so it must be a Mammal or a Bird. There is hair upon its body, but no trace of feathers; this is decisive, it is a mammal. The finger nails and the form of the teeth suffice to indicate the order Primates ("for the first shall be last, and the last shall be first"), which contains man and the monkeys. The large brain and relatively long legs with flattened soles show that it is one of the Hominidæ, of which the only living genus is *Homo*. The creature therefore is a man. The existing men are all considered to belong to a single species, *Homo sapiens*, but there are many races and subspecies. If the man has pale (so-called "white") skin, and hair which is not "woolly," he surely belongs to the subspecies *europæus*, and is zoölogically European, although politically perhaps American. This sounds cumbersome, but of course in practice the zoölogist takes a short cut to his conclusion. He perceives immediately that the animal before him belongs to a particular group, and has only to ascertain its position in that group. If he finds that there is no place for it in the system, that no description hitherto made fits it, he calls it "new," and proceeds to describe it and give it a name.

Classification aims to express relationship

3. So far, the object has been simply to sort objects and data [1] so that they can be easily found; but modern classification has much more ambitious purposes. It is nothing less than to express by means of the arrangements the actual "blood" (or "sap") relationship between organisms. Classification thus aims to reveal the actual plan of nature, not merely an artificial plan

[1] *Data* is the plural of *datum*. Those who should know better often use it as if it were singular.

devised for man's convenience. This is in its entirety an impossible ideal, yet we continually approximate more closely to it. The naturalist who understands this purpose finds even a check list, a bare list of genera and species, full of meaning and interest, provided it represents an attempt at classification.

CHAPTER TWENTY-THREE

THE PHYLA OF ANIMALS

Dominant groups of aminals

COULD we assemble together specimens of all the kinds of animals which have ever existed, the gaps which separate the phyla, classes, orders, and families would be filled by what we now call "missing links." Nevertheless, it would still be possible to distinguish the larger divisions, since the animals possessing their special characters would be much more numerous than the intermediate forms. We may illustrate the facts to a certain extent by comparison with objects made by man, which have undergone a kind of evolution, though by psychical instead of physical reproduction. No one doubts, for example, that the wheels of a locomotive and an automobile are alike modified forms of the original cart wheel. It would be possible to accumulate a collection illustrating numerous intermediate stages; yet if all wheels were to pass us in review, the highly adapted ones would be vastly more numerous than those leading up to them. As long as the automobile was in a relatively experimental stage, the number of these machines was comparatively small. As soon as the evolution had gone far enough to produce a highly serviceable machine, the number enormously increased. So, then,

Abundance of successful types

with the phyla of animals. The arthropod type, the vertebrate type, etc., represent successful mechanisms, which have increased and become diversified because competent to do so. The "missing links" represent Nature's experiments, perhaps well suited to particular times and conditions, but not able to occupy any large place in the world. A *phylum* (plural *phyla*) is the largest division of the animal kingdom. Most people think of animals as belonging to two great groups, the

vertebrates or backboned animals, and the invertebrates, without any spinal column. The vertebrates constitute a phylum; but the invertebrates cannot be thus grouped together, since the various phyla which they include are as distinct from one another as they are from the vertebrates. In several important respects a man is more like an earthworm than the latter is like a sea anemone.

Vertebrates and invertebrates

Since the phyla or grand divisions are so important, one would suppose that all naturalists would long ago have agreed as to their number and limits, if only as a matter of convenience. This is true in respect to several, but others are still in dispute. The questions involved have to do with the *amount* of difference necessary to establish a phylum. Naturally not all are equally distinct, and at some point it must be difficult to say whether a given group should be a phylum or a class, or whether we should compromise and talk about a "subphylum." It is assumed, however, that a phylum must not be "polyphyletic"; that is, a collection of unrelated organisms, not derived from any common ancestor possessing the characters of the phylum. For this reason the proposal to include the sponges among the cœlenterates appears highly objectionable, since it is improbable that the two groups have any common ancestor nearer than the Protozoa, or one-celled animals.

Disputed phyla

We may recognize the following phyla, which are more fully discussed farther on:

Phylum *Protozoa* (page 186)

Animals consisting of single cells, which may however be aggregated together in groups. They are all small, and are closely related to the *Protophyta* or one-celled

Protozoa and Protophyta

plants. All groups above the Protozoa are classed together as *Metazoa*, merely to emphasize the fact that they are *many-celled or compound.*

Phylum *Porifera* (page 207)

Sponges The sponges, in which numerous cells are associated together to form the individual, and these are specialized or modified in various ways.

Phylum *Cœlenterata* (page 210)

Cœlenterates Primitively radially symmetrical animals, such as the jellyfish and the sea anemone. The Ctenophora, jellyfishlike marine animals with eight longitudinal bands of cilia, constitute a subphylum.

Phylum *Echinodermata* (page 218)

Echinoderms Secondarily radially symmetrical animals, certainly more related to the worms, or even to the arthropods, than to the cœlenterates. They include the starfish, sea urchin, etc.

Phylum *Bryozoa* (page 226)

Bryozoa Small marine or fresh-water animals living in colonies.

Phylum *Brachiopoda* (page 227)

Lamp shells The lamp shells, resembling bivalved mollusks, but really related more nearly to the worms.

Phylum *Platyhelminthes* (page 229)

Flatworms Flatworms, such as the planarian, the liver, fluke and the tapeworm. The *Nemertinea* (page 233) may be regarded as another phylum, or a class under Platyhelminthes.

Phylum *Nemathelminthes* (page 233)

Roundworms The roundworms, with cylindrical unsegmented bodies, such as the hookworm.

Phylum *Trochelminthes*

Minute aquatic animals related to the worms, consisting in the main of the *Rotatoria* or rotifers (page 235), but including also the minute fresh-water animals called *Gastrotricha*, and equally minute marine *Kinorhyncha*, both so rarely observed that it is unnecessary to discuss them here. **Rotifers**

Phylum *Phoronidea*

Phylum *Chætognatha*

Phylum *Sipunculoidea*

These are small groups of marine animals, which cannot be satisfactorily referred to any of the other phyla. The sipunculoids, from the nature of their early stages, have been classed with the annelids, but they are not segmented. Such groups represent Nature's relatively unsuccessful experiments, which have never developed and spread as have the dominant phyla. They are very interesting to the zoölogist but of little consequence to the majority of people. **Small and relatively unsuccessful groups**

Phylum *Annelida* (page 237)

The annelid or segmented worms, including the earthworms and leeches. In the older classifications all the worms now separated as Annelida, Platyhelminthes, and Nemathelminthes were grouped together as Vermes. Pratt, in his *Manual of the Common Invertebrate Animals* (1916), separates the annelids, but treats all the above groups from Bryozoa to Sipunculoidea as subphyla of *Vermes*. This has the great advantage of avoiding the recognition of small and relatively unimportant groups as phyla, but the assemblage is an extremely miscellaneous one. It can be roughly defined as consisting of **Annelid worms**

bilaterally symmetrical animals consisting of many cells, without true segmentation and without any trace of a notochord, and without the special characters of the mollusks. The fact is that the bilaterally symmetrical type of animals gave rise to a great many independent branches, some of which assumed great importance; while others, though very distinct in structure, remained relatively insignificant.

Phylum *Arthropoda* (page 257)

Arthropods The jointed-footed animals, such as the insects, centipedes, crabs, spiders, etc.

Phylum *Mollusca* (page 243)

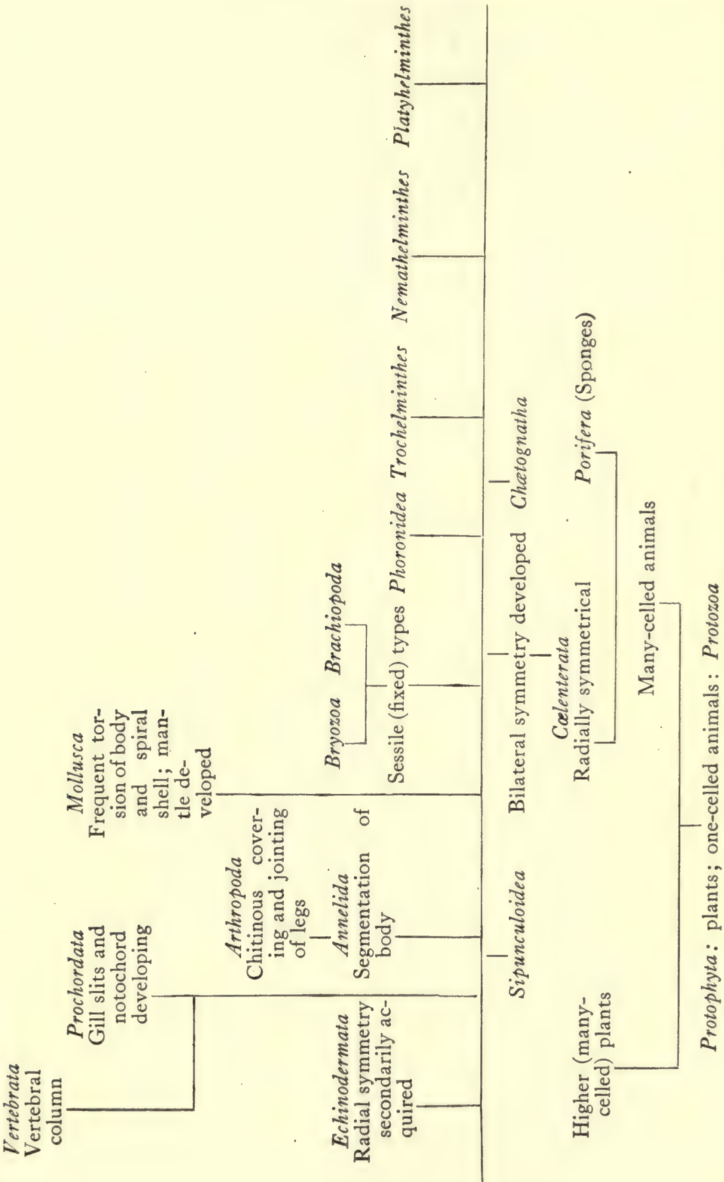
Mollusks The mollusks, including snails, slugs, clams, cuttlefish, etc. Although mollusks, annelids, and bryozoans are so different in appearance when adult, they show curious resemblances in the early stages.

Phylum *Prochordata* (page 320)

Prochordates The forms which, while lacking a vertebral column, nevertheless breathe by means of gill slits, and have at least in some stages a more or less developed notochord. A miscellaneous group, unsatisfactory because its divisions are so little related to one another. It is sometimes included with the vertebrates as a phylum *Chordata*.

Phylum *Vertebrata* (page 328)

Vertebrates The vertebrates; fishes, reptiles, amphibians, birds, and mammals, including man. The relationship between the various phyla may be roughly indicated as follows, the most primitive types being placed lowest in the diagram:

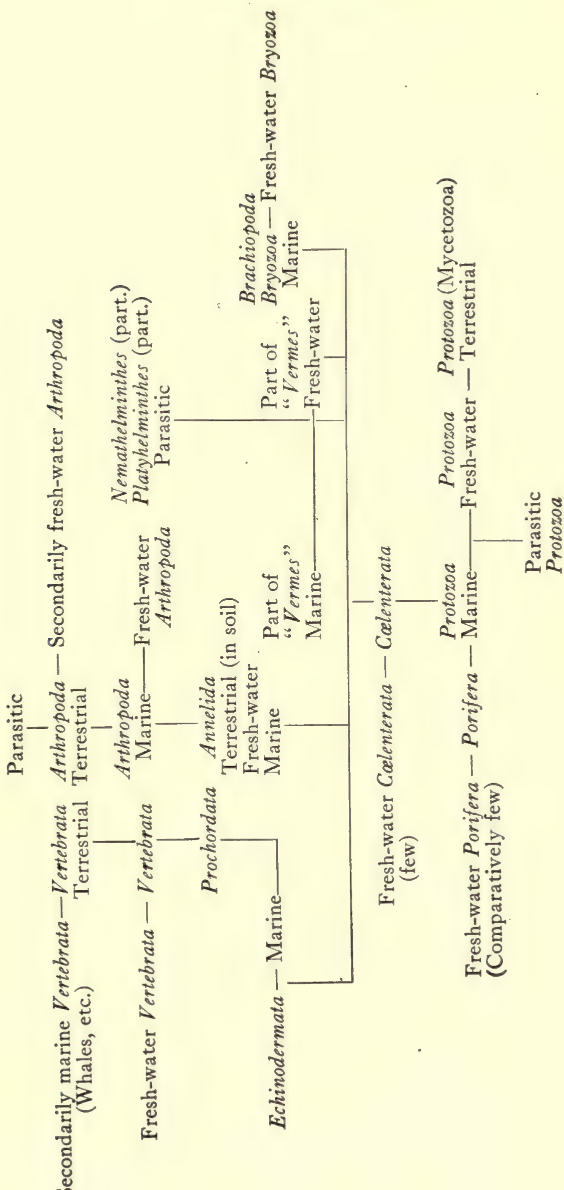


Vertebrata Vertebral column
Prochordata Gill slits and notochord developing
Mollusca Frequent torsion of body and spiral shell; mantle developed
Arthropoda Chitinous covering and jointing of legs
Echinodermata Radial symmetry secondarily acquired
Annelida Segmentation of body
Bryozoa
Brachiopoda
Sessile (fixed) types
Phoronidea
Trochelminthes
Nemathelminthes
Platyhelminthes
Sipunculoidea
Bilateral symmetry developed
Chætognatha
Cœlenterata Radially symmetrical
Porifera (Sponges)
Higher (many-celled) plants
Many-celled animals
Protophyta: plants; one-celled animals: *Protozoa*

Another way to regard the animals is from the standpoint of the mode of life. Assuming that the first life was aquatic, we can construct the following scheme, again beginning at the bottom (see diagram, page 185).

Adaptation

This diagram illustrates what Professor H. F. Osborn calls "adaptive radiation," the tendency for life to occupy all favorable situations, becoming modified to suit the environment. It will be noted, however, that there are limitations; not all groups occupy all environments.


Secondarily marine Vertebrata (Whales, etc.)
Vertebrata
Terrestrial
Parasitic
Arthropoda
Terrestrial
Secondarily fresh-water Arthropoda
Fresh-water Vertebrata
Vertebrata
Arthropoda
Marine
Fresh-water Arthropoda
Nemathelminthes (part.)
Platyhelminthes (part.)
Parasitic
Prochordata
Annelida
Terrestrial
Terrestrial (in soil)
Fresh-water
Fresh-water
Marine
Echinodermata
Marine
Part of "Vermes"
Marine
Part of "Vermes"
Fresh-water
Brachiopoda
Bryozoa
Fresh-water Bryozoa
Marine
Fresh-water Cœlenterata (few)
Cœlenterata
Cœlenterata
Fresh-water Porifera (Comparatively few)
Porifera
Protozoa
Marine
Protozoa
Fresh-water
Protozoa (Mycetozoa)
Terrestrial
Parasitic Protozoa

CHAPTER TWENTY-FOUR

PROTOZOA

Characters of Protozoa

1. *Protozoa* are usually defined as the simplest animals, consisting of only a single cell. Some forms, however, are said to be "colonial," existing in regular and well-defined groups of numerous individuals or cells. Thus the common fresh-water *Anthophysa* consists of pear-shaped flagellate cells united in compact clusters, often attached to a stalk. The slime molds or *Mycetozoa* form sporangia which are composed of many cells and have the appearance of fungi. Even in these cases, however, we do not find the development of *tissues* consisting of specialized cells, such as exist in other groups of animals. As if to make up for this lack of specialization, the single protozoan cell is often a remarkably complex structure, having many recognizable parts, or secreting an elaborately constructed shell. The Protozoa are readily distinguished from other animals if attention is paid to their characters, though the smaller worms may be confused with them on superficial examination. The latter, if examined more closely, will be seen to have various complex internal organs wholly lacking in Protozoa. When we look in another direction and try to separate the Protozoa from the Protophyta or lowest plants, the task becomes much more difficult. Indeed, many groups are claimed both by the botanists and the zoölogists. It might seem easy to refer the green *Euglena* to the plants, since it possesses chlorophyll, the characteristic coloring matter of green plants. It is found, however, that very closely related animals lack the green. There is another group which makes a shell of cellulose, which is also a typical plant product; but in other respects the organisms resemble

Protozoa. We are obliged to confess that there is no perfectly valid distinction between the lowest animals and the lowest plants; they grade one into the other.

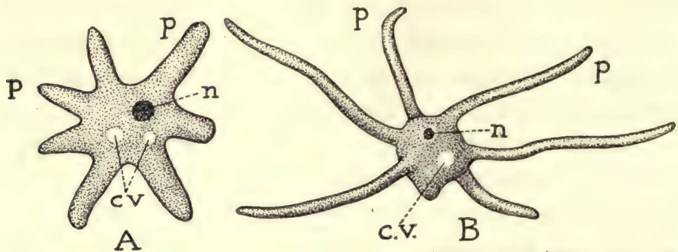
Variety and distribution of Protozoa

2. Protozoa abound in the sea and in fresh waters; they occur also in damp soil, while vast numbers of species are parasitic. The *Mycetozoa* may be regarded as Protozoa adapted to life in air. The species of Protozoa are excessively numerous, and in some cases they appear almost indefinitely so. The marine *Radiolaria*, described by Professor Haeckel of Jena, construct elaborate and beautiful shells of almost every conceivable pattern, reminding us of the infinite variety of snow crystals. The thousands of "species" named all have characteristic forms, but more recent researches indicate that many can be grouped as phases of variable species. Even so, however, the number of distinct kinds is very great, and the same may be said of another marine group, the *Foraminifera.* It is a remarkable fact that in spite of the low type of organization and the multitude of species, the different types of Protozoa are on the whole extraordinarily constant and of great antiquity. The very same species may be found in fresh waters on continents and islands, in the tropics and in cool countries, at sea level and in the mountains. Consequently the student who believes he has a new Protozoan is obliged to consider in comparison the species of the whole world, for the animal he has discovered in New York may have been described from Tasmania.

Flagellates

3. The principal types of Protozoa may be classified in groups or subphyla by the use of a few simple characters. The *Mastigophora* or flagellates move by means of a slender, undulating or vibratile thread of protoplasm called the *flagellum* (little whip). In certain types there are two or even more of these flagella, and

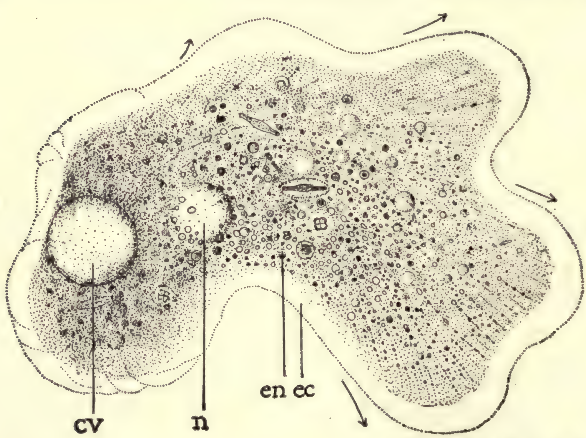
some of these show a distinct approach to the bacteria or other lowly organized plants. One of the commonest



Drawing by R. Weber, after Leidy

FIG. 36. *A*, Amiba diffluens. *B*, Amiba radiosa. Greatly magnified. *n*, nucleus; *c.v.*, contractile vacuole; *p.p.*, pseudopodia. The contractile vacuoles are excretory organs. They become filled with waste fluids and gases, which they eventually pour out on the surface of the body, contracting as they do so. Thus they possess, in a very simple form, functions of the lungs and kidneys of higher animals. They differ in function from the lungs in not being connected with the absorption of oxygen, which is taken in through the surface of the body.

flagellates in ponds and ditches is the elongated green *Euglena viridis*. In this animal one may notice a red

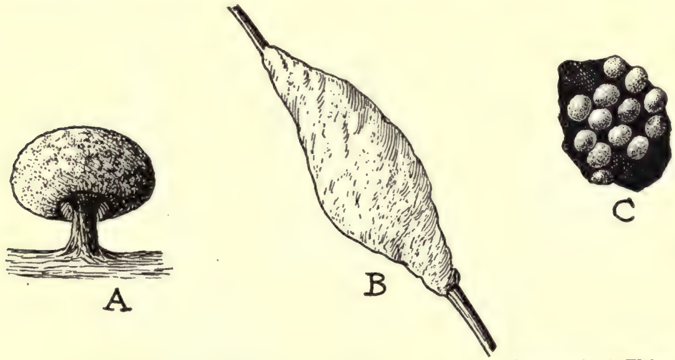


Drawing by W. P. Hay

FIG. 37. Amiba, magnified about 500 diameters. *cv*, contractile vacuole; *n*, nucleus; *ec*, ectoplasm; *en*, endoplasm. The endoplasm contains diatoms and other minute plants taken in as food and food masses in various stages of digestion and assimilation.

"eye spot," which probably enables the creature to distinguish differences in illumination, though it is quite unable to see any distinct object. In its simplest form the eye is a spot or area of coloring matter, which is changed by light and stimulates the living protoplasm. One of the marine flagellates is occasionally so abundant off the coast of California as to color the sea red, and to kill many fishes and other animals by clogging their gills. The *Noctiluca* is a relatively large flagellate, quite visible to the naked eye, which floats in the ocean near the surface, and when disturbed produces a brilliant light, so that the wake of an ocean steamer at night is often resplendent as though with fireworks. Other flagellates, such as the *Trypanosoma*, are parasitic within the bodies of animals.

4. The *Mycetozoa*, often regarded as plants, arise from a firm-walled *spore*, which in water gives birth to a *swarm cell.* These swarm cells are produced in great numbers, and are flagellate, resembling the Mastigophora. They swim about, feeding on bacteria. After **Slime molds**



Drawing by R. Weber

FIG. 38. Sporangia of Mycetozoa (after Lister). *A*, Sporangium of *Didymium*, on a fragment of a leaf; much magnified. *B*, Compound sporangium, or æthalium, of *Spumaria*, on grass; about twice natural size. *C*, Group of sporangia of *Trichia*, on wood; about four times natural size.

a time they coalesce to form a slimy wandering mass, the *plasmodium;* and this, now living in the air, usually on logs, forms a definite structure of characteristic appearance, which produces spores. The fructifying stage usually incloses the spores, and is called a *sporangium*, but in one group it has the spores on the outer surface and is termed a *sporophore.* Some sporangia are very large, that of *Reticularia lycoperdon* (lycoperdon, a puffball, which it resembles) is often 4 or 5 inches across. The plasmodium or slime stage is a multinucleate mass of protoplasm resulting from the union of a large number of cells, and as it grows the nuclei greatly increase in number. It feeds on dead plant tissue.

Parasitic Protozoa

5. The *Sporozoa* (spore animals) are parasitic Protozoa, without cilia, but in certain genera producing sexual forms, the male (sperm) cells then often flagellate. Reproduction is typically by *spore* formation (compare the *Mycetozoa*), the individual breaking up to

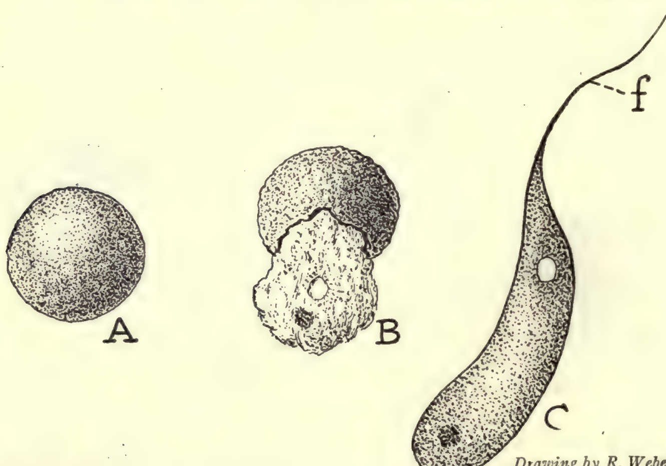
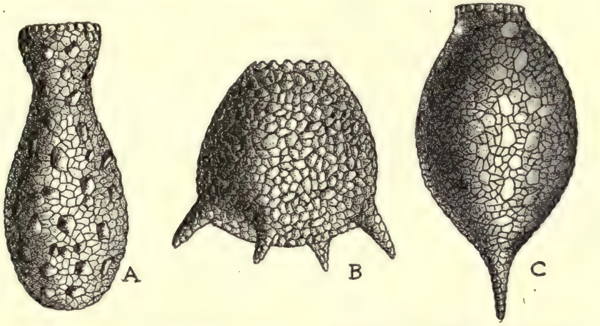


Fig. 39. Stages in the development of *Didymium,* one of the Mycetozoa (after Lister); magnified about 1400 diameters. *A*, Spore. *B,* Swarm cell escaping from a spore case. *C,* Swarm cell; *f,* flagellum.

give rise to a great number of smaller organisms. In the malaria parasite, which is conveyed to man by the



Drawing by R. Weber (after Leidy)

FIG. 40. Shells of three species of Difflugia. *A, D. capreolata.* *B, D. corona.* *C, D. acuminata,* variety *inflata.* Although *Difflugia corona* presents marked variations, it never assumes the form of *D. acuminata* or *D. capreolata.* Distinctive characters are not confined to the shell; one species (*D. rubescens*) has the contained animal of a beautiful brick-red color. Greatly magnified.

mosquito, sexual reproduction occurs in the body of the insect, but asexual sporulation takes place in the human blood.

Gregarines are sporozoans usually found in the alimentary canal of insects and other arthropods. One common species lives in the earthworm.

The Amiba and its relatives

6. The *Rhizopoda* include many of the most common fresh-water Protozoa, which possess neither flagella nor cilia, but move slowly about by means of projections of the body, called *pseudopodia* (singular, *pseudopodium*) or false feet. The *Amiba* (or Amœba) is a naked form common in ponds.[1] When at rest it is spherical, but its protoplasm flows outward to form elongated pseudopodia. Within the body can be seen *nucleus* and *con-*

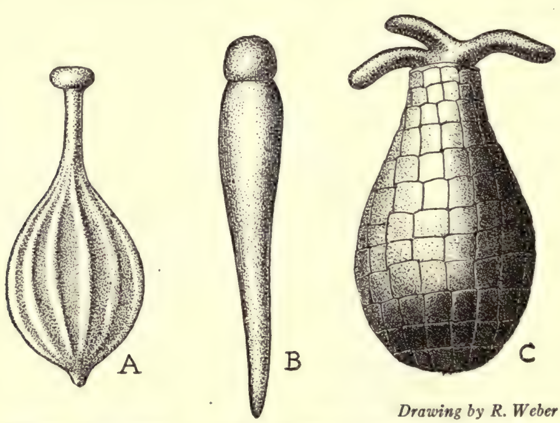
[1] This animal was originally called *Proteus*, on account of its changing form, but it was found that the name had previously been used for another animal. *Amiba* was then substituted, with the spelling here given, though it is more usual to write *Amœba.*

tractile vacuole, and also frequently various objects taken in as food. Many other rhizopods form shells of various kinds, often looking like little jars or flasks, or flattened and circular, like buttons. In one genus (*Quadrulella*) the shell is composed of quadrangular plates; in another (*Difflugia*) it consists principally of sand grains united together by a secretion of the animal. In one family the pseudopodia are threadlike.

Related to the Rhizopoda are the *Heliozoa* or "sun animalcules," a common representative having a spherical form and long, raylike pseudopodia, resembling conventional pictures of the sun. The marine *Radiolaria*, already mentioned, are related to the Heliozoa.

Ciliates or Infusoria

7. The *Infusoria* move by means of *cilia* (singular, *cilium*), which are very fine eyelash-like projections from the body, moving like the oars of a boat and causing the animal to be rapidly propelled through the water. Reproduction is usually by simple transverse



Drawing by R. Weber

FIG. 41. Types of Protozoa. *A*, Shell of Lagena (*Foraminifera*) Marine; *B*, *Stylocephalus*, a gregarine parasitic in beetles; *C*, *Quadrulella*, a freshwater Rhizopod. All much magnified.

division, but the individuals may frequently be seen to *conjugate*, whereby a certain amount of their protoplasmic substance is interchanged. This differs from

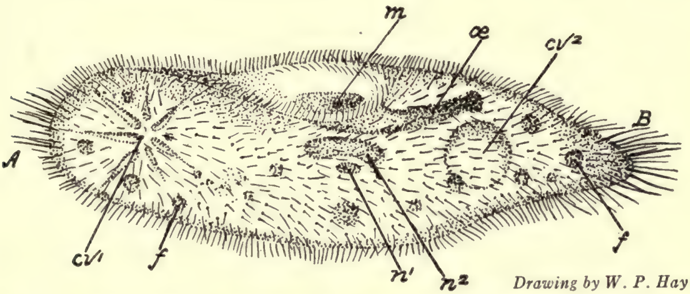


FIG. 42. Paramecium. *A*, anterior; *B*, posterior end; *m*, oral opening; cv^1, anterior contractile vacuole in contraction; cv^2, posterior contractile vacuole in state of expansion; *f*, food masses; n^1, micronucleus; n^2, macronucleus. Greatly magnified.

the sexual reproduction of the Sporozoa, and it can hardly be said that sex exists, since the conjugating individuals are alike. In the *Suctoria* cilia are nearly always absent in the adult, which possesses tentacles instead.

Cilia are by no means confined to the Protozoa; thus they exist in the human windpipe, where they serve to remove the accumulations of mucus and dust.

CHAPTER TWENTY-FIVE

PROTOZOA AND HEREDITY

Races of Protozoa

1. The species of fresh-water Protozoa, widely distributed over the earth, are remarkably constant in what we call their specific characters. When minutely studied, however, they are found to vary within rather wide limits, and it appears that there exist numerous minor races, too much alike to be recognized as distinct species. Professor H. S. Jennings of Johns Hopkins University has shown that the intensive study of these minute animals will yield results of the highest interest in connection with the problems of heredity. The slipper animalcule, Paramecium (plural, *Paramecia*), is a ciliated form extremely common in water containing decomposing vegetable matter. It is transparent, so that all its characters can be readily observed, while its rapid rate of reproduction makes it possible to follow it through numerous generations. As it does not necessarily conjugate, but is capable of reproducing for very long periods, if not indefinitely, by simple division, it is possible to eliminate the confusion due to biparental inheritance.

Pure lines

"Pure lines" can be obtained, all directly descended from a single ancestor. Such pure lines have members with identical hereditary composition, although individuals may show conspicuous differences due to environmental conditions. Even in a watch glass it is impossible to make the conditions absolutely uniform. The lower layers of the water are likely to contain accumulations of bacteria, which are injurious to the protozoans. Individuals entering the less favorable surroundings will have their vitality somewhat impaired, and thus they show less energy in swimming to

the upper layers. By degrees, just like men, they become regular inhabitants of the slums, and show the effects of this in their appearance. Consequently Jennings found that even within a pure line the individuals differed in size, the largest being very much larger than the smallest. Yet if he selected one of the largest and one of the smallest to start new lines, their progeny varied over the same average under similar conditions. It made no difference whether the ancestor of the new group was large or small, because these differences were not inherited. Similarly, among people, the descendants of an ignorant man, who had never been educated, would not necessarily show any inferiority to those of one who had had every advantage.

Races of Paramecium

2. Nevertheless, when various "wild" Paramecia, of different sizes, were selected to start pure lines, it was found that there were races differing in average size. Jennings isolated eight such races. There were also races differing in various other characters. Each one of these races varied, owing to environmental effects, but the ranges of variation were not the same. Thus one race might vary from *A* to *D*, another from *B* to *E*, a third from *C* to *F*. Now the smallest member of one race might be much smaller than the largest of the next, yet if the first race averaged largest, its small representative would give rise to animals averaging larger than the progeny of the large member of the other race. Thus the result depends upon the hereditary composition of the race, and not upon the appearance of the individuals. *It is often impossible to determine, on mere inspection, whether a character is due primarily to heredity or environment.* Of course all characters are actually due to the combination of both factors, but one or other may be responsible for the conspicuous deviation from

Effects of heredity and environment

the average. Similarly, among plants, smallness may be due to growth under unfavorable conditions, such as lack of moisture; or may be (as in the case of the dwarf sweet pea) an inherited character. Among sunflowers, the seeds of large kinds produce dwarfs when grown in shade, but no amount of sunshine will make the small kinds grow tall. Among ourselves, we are continually puzzled to know whether the qualities of individuals are primarily inherited, or are principally due to favorable or unfavorable surroundings. No one, trying to judge himself, can be quite sure how much to attribute to each of the two factors. Yet the breeder of animals or plants, especially if he can keep many successive generations under observation and experiment at will with environmental factors, may determine the relations between cause and effect with a high degree of accuracy. The experience so gained enables him to form reasonably accurate judgments in many other cases on mere inspection, or with a limited history to guide him.

Constancy of determiners

3. Since the selection of large or small (or otherwise differing) Paramecia among the members of a pure line did not produce any change in the characters of the race, it was held that the hereditary qualities remained constant during the period of the experiment. Experiments of this sort were continued long enough, not only with Paramecia but with other organisms, to lead to the conclusion that actual changes in the germ plasm (original variations) were extremely rare, to say the least. This appeared to be equally true of animals and plants; thus the Vilmorin wheats remained the same after many years of selection. There remained, however, this difficulty — that since selection could be based only on tangible or visible characters, it was difficult or impossible to choose the deviations due to

Experiments with Difflugia

heredity (if there were any), instead of the probably much larger ones caused by the environment. To avoid this difficulty Jennings began new experiments with a quite different protozoan, the *Difflugia corona* (Fig. 40, *B*). This is a shelled rhizopod, the shell being made of grains of sand embedded in a chitinous secretion, and presenting a variable number of projecting spines. When division takes place, to form a new individual, the shell is formed, and it cannot be altered subsequently. The shells are readily preserved, so that many successive generations may be directly compared. It was found that the animals differed in the size and shape of the shell, the length and number of the spines, etc. After many generations, the descendants of a single ancestor, selected for various characters, were found to have actually diverged from one another, the difference being inherited. This appears to contradict flatly the evidence derived from Paramecium, but it may well be that species differ in the mutability of their germ plasm, or are mutable at certain times and not at others. It must be remembered that the species of *Difflugia* are extremely widely spread over the world, and are essentially constant in their characters. This proves that they are of great antiquity, and suggests that however the hereditary qualities may have varied, they have very rarely done more than oscillate about a mean. It may be that the complex molecules forming the determiners are never rigidly constant for great lengths of time, but change within small limits, which usually elude our powers of observation. This might be true, and yet the chemical oscillation, if we may so term it, might be strictly limited under ordinary circumstances, so that the termination of a series of generations would find the organism practically as it was at the beginning. Only

by the selection and isolation of the minor varieties could these be established as permanently differing strains.

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CHAPTER TWENTY-SIX

PROTOZOA AND DISEASE

Origin of parasitism among Protozoa

1. Parasitism has arisen independently in various groups of Protozoa. It represents an effort on the part of these animals to extend their range, to find new opportunities for existence. The fluids within the bodies of animals appear to be especially suitable for protozoan life, but the species which are found as parasites are not identical with those living free. They have special characters which fit them not merely for parasitic life in general, but for life in a particular kind of animal, the involuntary host.

We may imagine the evolution of a parasitic protozoan type to have been somewhat as follows. Originally an inhabitant of the waters surrounding or imbibed by the prospective host, it finds its way into the alimentary canal, where it becomes established and at the same time modified for the new mode of life. Then, after a time, it penetrates the walls of the gut, and occupies the blood or some other body fluid, and is now an obligatory parasite. All this will doubtless take a very long time, and requires perhaps millions of generations of the evolving organism. That it should happen at all is rather surprising, when we consider the extraordinary stability of the free-living species. These latter have remained true to type in the presence of tropical heat and arctic snows, and through immense periods of time.

The parasites have certainly undergone more rapid change, fitting themselves for life in various hosts, some of which are themselves of comparatively recent evolution. Herein they met the necessities of the situation, showing a power of adaptation where nothing else would

suffice. Even so, however, they departed little, as a rule, from the primitive protozoan structure, and some of them would hardly be recognized as parasites if taken out of their proper environment. The evolution has been largely physiological, a change in abilities and reactions rather than in outward form or obvious structure.

The parasitic ameboid Protozoa

2. Among the Rhizopods we find ameboid species, known as *Entamœba*, inhabiting the alimentary canal. One of these types is the cause of dysentery, a disease especially prevalent and fatal in warm countries. The cause of rabies or hydrophobia, long in doubt, is now believed to be an ameboid protozoan, which establishes itself in the nervous system of the victim. A protozoan has also been connected with smallpox, while the existence of other disease-producing, amiba-like organisms is inferred rather than certainly known. In the case of yellow fever, for example, the virus or organism cannot be seen, nor can it be isolated from a liquid by means of

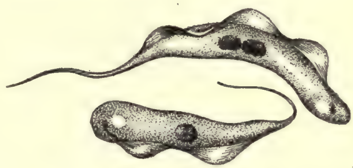
Filterable viruses

filtration. It belongs to a class of *filterable viruses*, recognized only by their effects. The list of such disease-producing but invisible creatures is being increased as new observations are made, and from the close analogy between their effects and those due to Protozoa we infer that they probably belong to this group. Possibly some day microscopical technique will be improved sufficiently to enable us to see and study the structure of these infinitesimal beings, but at present it appears impossible to combine an image sufficiently large for vision with adequate illumination.

The disease-causing flagellates

3. The flagellate Protozoa or Mastigophora include the genus *Trypanosoma*, which is the cause of some of the most serious diseases known. Trypanosomes are long, pointed animals, with an undulating membrane along the side, the margin of which extends as a flagel-

lum from one end. Species of trypanosomes occur frequently in the blood of various animals, without necessarily giving rise to any ill effects. Others are extremely dangerous, one producing the disease called "sleeping sickness" in man, another the nagana disease of domestic animals in Africa. The Ciliata or ciliate Protozoa are usually thought of as free living, but even these include parasites, such for example as the *Opalina*, common in the frog. This is an oval species, capable of being extended to look like a worm. The most characteristic parasitic Protozoa are, however, the *Sporozoa*, or "spore animals," which have neither cilia nor flagella, and reproduce mainly by the formation of spores, or small particles arising in great numbers at one time from the parent. Here we include a division called *Hemosporidia*, living in blood, members of which cause malaria, tick fever, and apparently Rocky Mountain spotted fever.



Drawing by R. Weber (after Report of Wellcome Research Laboratories)

FIG. 43. Trypanosome of camel, greatly magnified.

The Sporozoa

Alternate hosts of parasitic Protozoa

4. It is not difficult to understand how the organism of dysentery, which occupies the alimentary canal, can be acquired through drinking infected water. In tropical countries the prudent traveler boils all his water, or uses distilled water. But what about the malaria parasite, found in the blood, or that of sleeping sickness, also inhabiting the internal fluids? Can these animals, in the course of one or a few generations, pass into the alimentary canal, and thence into the blood? The supposed course of evolution is not thus repeated, nor does it appear that the origin of parasitism in these types

was necessarily in the bodies of warm-blooded animals at all. They are parasites of Arthropods, which are conveyed to mammals and other animals when the insects or arachnids suck their blood. Thus the parasites have alternate hosts, belonging to very different classes of animals, both of which must be present for the completion of the entire cycle of normal activities. It is noteworthy in this connection that the alimentary canals of many Arthropods, such as insects and centipedes, are inhabited by Gregarines, a group of Sporozoa which have nothing to do with disease in higher animals. We may infer, though we can never prove, that millions of years ago, in Carboniferous times, the great cockroaches then so abundant were infested by these parasites, at a time when no warm-blooded animals had evolved. We do not know how it first came about that alternation between a vertebrate and an invertebrate host was established, or by what means a parasite was able to accommodate itself to the strange environment of warm blood. We do know, however, that this happened more than once; for trypanosomes and malaria parasites are little related, and certainly evolved from quite different branches of the great protozoan stem.

Economic results from study of Protozoa

5. With the establishment of the theory of alternate hosts, a great new field of preventive medicine was opened up. It would be difficult to exaggerate the value of the various discoveries which have given us knowledge of the course and mode of transmission of yellow fever, malaria, sleeping sickness, and other diseases. Through them the most fertile regions of the world are opened up to the white man; and while innumerable deaths are prevented, our food supply is increased enormously. We have only begun, as yet, to take advantage of the offerings of science in this direction; but it is

within the memory of all mature persons that the region of the Panama Canal, once a hotbed of pestilence, has been made healthful. In the course of the investigations leading up to these results, many men have suffered illness or even death, but this does not deter medical investigators from taking risks which they, better than any others, understand. At an early stage in the investigation of the transmission of yellow fever in Cuba, Dr. J. W. Lazear of the United States Army lost his life; but this did not prevent his colleagues, Reed, Carroll, and Agramonte, from continuing the work, until they had proved conclusively that this disease is brought about only through the bite of a particular type of mosquito, known as *Stegomyia*. The mosquito does not itself cause the disease, but conveys the organism which produces it. With this information it was easy to understand why yellow fever never became permanently established in the North, for *Stegomyia* lives only in warm temperature and tropical regions. It was also possible to see the futility of a great deal of disinfection work which had formerly been regarded as the most important means of protection. A man may sleep in a bed which has just harbored a yellow-fever patient, and suffer no evil consequences. More especially, however, it was possible to get rid of the disease by destroying the breeding places of the mosquitoes, the whole yellow-fever problem being thus rendered comparatively simple and easy of solution. There is no longer any excuse for the prevalence of yellow fever in a community. **Yellow fever**

6. In the case of malaria (ague or swamp fever) it was also found that mosquitoes were to blame, but this time an entirely different kind, belonging to the genus *Anopheles*. The causative organism of malaria, called *Plasmodium*, is readily visible under the compound micro- **Malaria**

scope, and can be traced without difficulty in both its hosts. Long ago people connected malaria with swamps, — the word itself, from the Italian, meaning "bad air," which was supposed to rise at night from the stagnant waters. We now know that *Anopheles* breeds in the swamps, and flies at night; it is the swarm of mosquitoes, which arise and bite whoever may be accessible, that bring about the disease. The malaria organism has a double life-cycle, reproducing sexually in the body of the mosquito and asexually in the blood of man. Thus we must regard the mosquito as the primary host, or the more important of the two from the standpoint of the parasite. At the time of reproduction or sporulation in the blood, the affected individual suffers a "chill," followed by fever, which occurs at regular intervals while the active phase of the disease lasts. There are several types of malaria, and at least three different species of parasites have been distinguished, — all, however, carried by *Anopheles*. The proof of the connection between mosquitoes and malaria was established not only by the observation of the organisms in the blood, but also by the experimental transmission of the disease. It was also shown experimentally that men could live and work in the most malarious districts, and suffer no harm, provided they were protected from mosquitoes at night. In localities where there is no *Anopheles*, malaria cannot be acquired, though persons who have acquired it elsewhere may continue to suffer at intervals. *Anopheles* may even be present, but unless it is infected by the *Plasmodium*, no malaria results.

Sleeping sickness and nagana

7. The important African diseases due to trypanosomes are also carried by insects, but of a different family of Diptera or flies. In this case the alternate hosts are species of tsetse fly, of the genus *Glossina*.

These look somewhat like house flies, but are recognized by the long, straight proboscis projecting in front of the head, and by the way in which the wings are folded over

From drawing by John T. Scott

FIG. 44. Tsetse fly (*Glossina palpalis*), female; × 5 diameters. From a specimen collected in Southern Nigeria, Africa, by G. Garden, April 28, 1909. This fly is widely distributed over tropical Africa. It has a formidable proboscis, and sucks the blood of man and other animals. In so doing, it transmits a minute protozoan, called *Trypanosoma gambiense*, which produces in man and monkeys the disease known as "sleeping sickness." From this disease many thousands of the inhabitants of Africa have perished. Another related protozoan, *Trypanosoma brucei*, is carried by a different tsetse fly, *Glossina morsitans*, and produces in cattle and horses the highly fatal disease called "nagana." Tsetse flies once existed in Colorado, as is proved by fossils found at Florissant. They may well have transmitted the organisms causing disease, and thus been instrumental in exterminating some of the larger animals. Thus we find here, as throughout the realm of animate nature, that all living things are actors in the great drama of existence, and those which seem at first to have the most insignificant parts often prove able to influence an ever widening circle of events. Man and his affairs cannot be understood without reference to the humblest forms of life.

the back, the ends not projecting as they do in ordinary flies. *Glossina palpalis* is the principal transmitter of sleeping sickness, or rather of the protozoan which causes it. Through the extension of commerce in tropical Africa the disease has been enormously extended, and has destroyed the lives of untold thousands of native people. The sickness is of long duration, and eventually the victims sleep to death. Another tsetse fly, *Glossina morsitans*, carries the trypanosome of nagana disease, which makes it impossible to keep cattle in some districts. It is found that the large wild animals of Africa harbor the parasite, without suffering any serious consequences; hence they serve as a reservoir from which the tsetse flies may always renew the supply. At Florissant, in Colorado, several species of fossil tsetse flies have been found, and it is surmised that at one time these may have been carriers of the organisms of disease. Today there are no species of *Glossina* living in the Western Hemisphere.

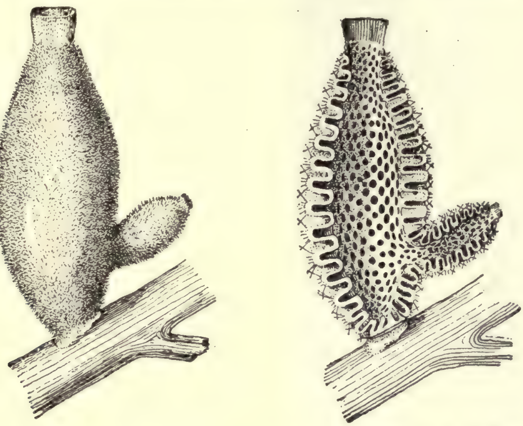
Tick fever

8. Other disease-producing Protozoa, belonging to the genus *Babesia*, are carried by ticks. One of these gives rise to a fatal affection of cattle, in which the red blood corpuscles are broken up. In the Southern states cattle have acquired a tolerance of this parasite, just as in tropical countries the negroes are relatively tolerant of malaria. When such cattle, infested by ticks, are driven northward, the ticks may leave them and bite Northern cattle, which then succumb to the disease. The cause of Rocky Mountain spotted fever, a disease which is very fatal to men in certain districts, is also carried by ticks, but of a different species from those living on cattle. Fortunately the disease is at present rare and local, though the ticks are widespread.

CHAPTER TWENTY-SEVEN

SPONGES

1. The Sponges or Porifera (pore-bearing) constitute a very distinct phylum of animals, little related to any



Drawing by W. P. Hay

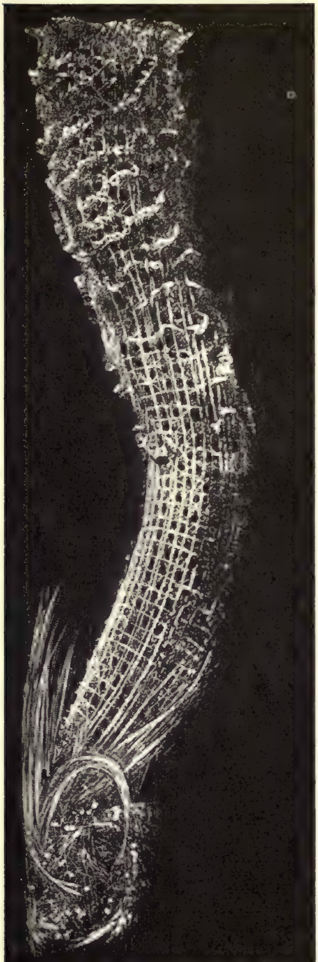
Fig. 45. A simple sponge attached to a seaweed. On the right the same animal is shown in vertical section.

others. They are all aquatic, the great majority being marine. They have existed in great abundance for many millions of years, as is proved by their fossil remains. The genera and species are very numerous, and of very diverse structure and appearance; yet all are sponges, and there has apparently been no tendency to evolve into anything higher. There is a similar lack of progressive tendencies in the life of the individual sponge. The ovum or egg cell is fertilized by a minute flagellated sperm-cell, as in the higher animals. The fertilized cell becomes a ciliated larva, which swims about for a time and then becomes fixed to some object and develops into a sponge. There is a veritable metamorphosis, the creature becoming entirely changed, and

General characters of sponges

Mode of life

finally we have, in typical cases, a structure resembling a hollow vase perforated with holes. The central cavity has an opening above called the *osculum* (little mouth), while the walls are perforated by *pores*. During life water enters by the pores and passes out through the osculum. The inner cavity is lined with peculiar flagellated cells, the base of each flagellum being surrounded by a little cup or collar. The whiplike movements of the flagella cause the necessary flow of water. Thus the sponge, beginning life as a free-living larva, as if on the way to produce a relatively high type of animal, assumes a vegetative form, and appears almost to lose its integrity as an individual. The cells of which it is composed are less definitely associated together than those of the higher animals, so that the distinction between a sponge and an aggregate type of protozoan is not so radical as might at first appear. In the sponge, however, the cells are not all similar, either in form or function.



From "Animate Creation"

FIG. 46. Skeleton of *Euplectella aspergillum*, or Venus-cup sponge, composed of flinty fibers; about ⅓ natural size.

2. Sponges are said to possess a skeleton, but the term is employed in a very loose sense. We mean that there are fibers or spicules which give the structure its stiffness and prevent it from falling to pieces even when all the living material has been removed. In an ordinary bath sponge we see this skeleton, consisting of a horny substance called *spongin*, which in life is merely the framework of the animal. One group of sponges has a skeleton made of calcareous or limy spicules, while others have the spicules siliceous or flinty. This property of secreting different materials, limy or flinty according to the species, is found also in Protozoa. The hornlike substance, spongin, is said to be allied to silk. The spicules resemble little crystals in form, and it is characteristic of the relatively unorganized and vegetable-like growth of the sponge that these units are scattered through the substance, instead of being articulated to form a definite mechanical unit comparable to the skeleton of a vertebrate. It must be said, however, that the structure of the whole animal is often complicated and beautiful, especially in the flinty forms.

The sponge skeleton

There is no special nervous system, and therefore the actions of the cells are largely independent of one another, as though they were distinct individuals. It is well to remember in this connection that even in ourselves, with our brain and highly organized nervous system, the white blood cells behave essentially as independent units.

CHAPTER TWENTY-EIGHT

CŒLENTERATA

Protozoa and Metazoa

1. ANIMALS are divided into the *Protozoa* and *Metazoa.* The Protozoa, as we have seen, consist of single cells, or of aggregations of similar cells. The Metazoa are the multicellular or many-celled organisms, including, of course, all the higher forms. If we set aside the sponges as representing a quite distinct line of development, we may recognize in the typical Metazoa certain characteristics common to the whole series, apparently indicating evolution from a single stem. The cœlenterate, such as the jellyfish or hydra, is essentially a sac with two layers of cells, of which the inner is called the *endoderm* and the outer the *ectoderm.* The terms "hypoblast" and "epiblast" are used by authors in the same sense. Now these layers may be seen in the early stages of the highest animals, and in development they form definite structures. Thus the inner layer gives rise to the various parts connected with the alimentary canal, but from the outer is developed the nervous system. A middle layer, becoming distinctly defined in the higher groups, produces the skeleton of the vertebrate and other important structures. This middle layer (mesoderm or mesoblast) is not present in the cœlenterates, though materials derived from the two primary layers form a poorly organized *mesoglœa* lying between them.

Endoderm and ectoderm

Thus it appears that the basic structure of the higher animals was laid down in the lower Metazoa; and what was then developed, millions of years ago, conditions the development of man himself today.

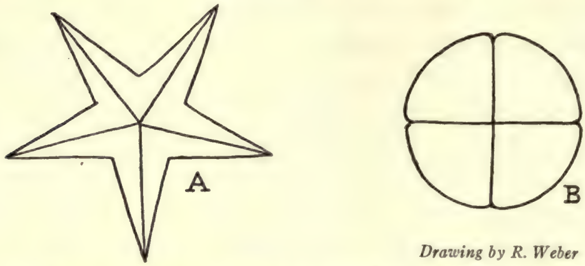
2. On the other hand, the cœlenterates lack very important structures. They possess a single internal

cavity, serving as a stomach and having a single orifice. They have therefore the form of a vase or bottle, and to that extent resemble the sponges, though the resemblance is wholly superficial and represents no community of function or descent. In the other Metazoa, beginning with the echinoderms and worms, there appears a second body cavity, the *cœlom*, between the intestine, or stomach, and the body wall. In their vaselike form with a single cavity, the cœlenterates thus stand at the base of the metazoan series, and in a sense we may say that a jellyfish is less like a sea urchin than the latter is like a man. **Relative simplicity of cœlenterate structure**

When we have once grasped the essential features of the cœlenterate structure, it is not difficult to detect them in the most diverse members of the group. As the position of the animal differs according to the species, or even in the same species at different periods of life, we do not speak of the upper and lower surfaces, but of the *oral* and *aboral* sides. The oral side is that which exhibits the mouth opening, and the aboral that opposite to it. Thus in a sea anemone the upper side is oral, and the mouth is directed upward. In a jellyfish the lower side is oral, and the upper corresponds to the base of the sea anemone. **The oral and aboral surfaces**

3. The cœlenterates possess radial symmetry, in the manner of a flower. This early attracted the attention of naturalists; hence the name "sea anemone," and the scientific term *Anthozoa* (flower animals), applied to the great group including the sea anemones and most of the coral animals. Others form plantlike colonies, and were in some cases originally described as seaweeds. Such are termed *zoöphytes*, the name meaning in Greek "animal plants." The radial symmetry of the cœlenterate is said to be primitive, whereas that of the echino- **Radial symmetry**

derms (such as the sea urchin) is secondary or derived, — a response to the needs of sedentary life. These



Drawing by R. Weber

FIG. 47. Diagram illustrating the radial symmetry of a starfish (*Echinodermata*), *A*; and a medusa (*Cœlenterata*), *B*.

facts are determined from a study of the early stages, but it is also to be noted that the radial segmentation of a jellyfish is fundamentally different from that of an echinoderm. In the echinoderms, as A. H. Clark pointed out, the divisions are lines of weakness; hence the typically five-rayed condition, which provides that no such line will go straight across the body. In the jellyfish the divisions are marked by lines of greater strength, and hence when continued across the body give added rigidity. We therefore find quadripartite cœlenterates.

Two modes of reproduction

4. The primitive character of the cœlenterates is shown also by their modes of reproduction. They possess sex, but also reproduce by budding. Individuals are produced as lateral buds, which live for a time as parasites attached to the parent, and finally become detached and independent. This is a natural process, but a fresh-water *Hydra* may be cut up into a number of pieces, and each one will grow into a perfect individual. In certain groups the asexual mode of reproduction is lost, and there are separate sexes as in higher animals. In the fresh-water *Hydra* the male and female generative cells may be produced by the same individual, when

it is said to be a hermaphrodite. When the animals are well fed, they usually show female characters.

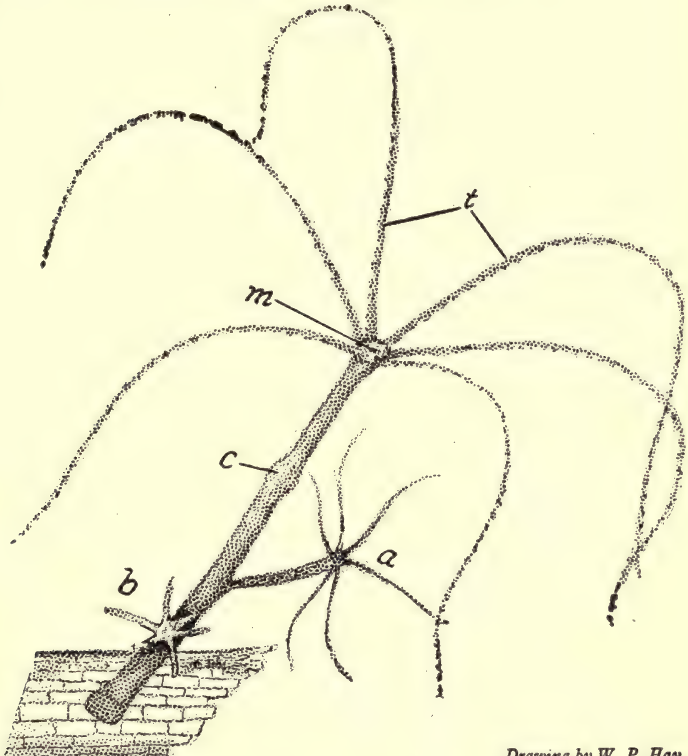


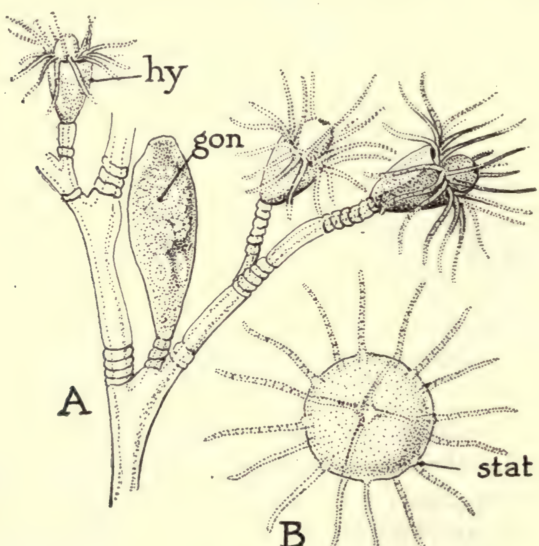
FIG. 48. A hydra (*Hydra oligactis*), with two buds, *a* and *b*; *m*, mouth; *t*, tentacles with batteries of nematocysts; enlarged about 5 diameters.

Divisions of Cœlenterata

5. The cœlenterates are divided into three great groups, the *Hydrozoa* or Hydromedusæ, the *Scyphozoa* or Scyphomedusæ, and the *Anthozoa*. The first contains the hydroid zoöphytes, hydra and other less-known animals; the second the true medusæ or jellyfishes; the third the sea anemones and their relatives. Nearly all these animals are marine, but *Hydra* is a common fresh-

water animal; and a few kinds of small fresh-water medusoids (Hydrozoa) are known. Great excitement was caused, many years ago, by the discovery of the first of these medusoids in the water-lily tank in the Botanic Garden in Regent's Park, London.

Hydrozoa The Hydrozoa are remarkable for the branching colonies of many of the species. This type of structure may be thought of as due to a budding process, — the buds, as in a plant, remaining attached, with nourishment flowing from one to the other. It results from this that specialization is possible, and we find the individuals or persons of the colony taking on different functions. Some feed, others reproduce, while others have stinging properties and serve for defense. On examin-



Drawing by W. P. Hay (after Nutting)

Fig. 49. *A*, a small portion of a colony of Obelia commissuralis, one of the Hydrozoa, common on American coasts. *hy*, hydranth in a hydrotheca; *gon*, a gongangium containing young medusa. *B*, a medusa; *stat*, statolith; greatly enlarged.

ing a branching hydroid, one may often see small, cup-like structures attached to the stem. These are the *hydrothecæ*, and in them are set the hydroid persons, more or less resembling minute hydras. The reproductive persons may remain permanently attached to the colony, or, in other species, they are set free as swimming medusæ, whereby the range of the species is extended. The word *medusa*, as applied to a jellyfish or similar animal, is derived from the Medusa of ancient fable, a woman with snakes for hair. The naturalists of early times, who had a good deal of imagination, fancied a resemblance between the head of the medusa and the jellyfish, with its snakelike pendent tentacles. When the reproductive person or medusoid is set free, the base becomes the upper surface and the oral side is below. These medusoids have been found and studied by naturalists in many cases without reference to the hydroid stage; consequently two systems of classification have sprung up for stages of the same animals. By degrees, however, the connection between particular colonial forms and their medusoids is being established, and the classifications are amended accordingly.

The medusa

Certain medusoids possess small vesicles at the margin of the bell or umbrella, and these vesicles contain *statoliths*, — hard, stony bodies which are supposed to enable the animals to perceive their position in space. The force of gravity, acting on the statoliths, produces a downward pressure to which the animal reacts. Thus the function of these organs is something like that of the semicircular canals in the human ear, but in these latter the mechanism is entirely different. Nature attains the same or similar ends in wholly diverse ways.

Scyphozoa, the jellyfishes

The *Scyphozoa* are not very closely allied to the Hydrozoa, and it is even probable that they acquired the

medusa form independently. Some of them are of great size, the disk or umbrella as much as 4 feet in diameter. One specimen was found to weigh 90 pounds, but of course this was mainly water. Large jellyfishes cast up on sandy shores form only thin films when dried by the sun.

The sea anemone and its relatives

6. The typical anthozoan, as represented by the sea anemone, is a more or less columnar animal, with the upper end furnished with numerous tentacles, which serve for catching the prey. In the middle of the upper surface is seen the mouth opening, which is usually more or less oval or slitlike, giving the animal an incipient bilateral symmetry. The mouth is the upper end of the throat or *stomodæum*, the lower end of which really corresponds to the mouth of the hydra. The stomach cavity is not a simple sac, as in the hydroids, but is invaded by a series of leaflike projections from the sides, called the *mesenteries*. In the coral-forming species the septa of the coral alternate with the mesenteries, and hence it is possible to determine to a considerable extent what form the soft parts had in fossil corals of vast antiquity. The Alcyonaria (Fig. 9, page 39) constitute a peculiar subclass of Anthozoa, in which the individuals possess eight pinnate or featherlike tentacles. All produce a limy so-called skeleton, and the various remarkable colonial forms, as seen after the death of the animals, resemble columns of basalt or other curious structures, little suggestive of anything living. It is only by the careful study of the living creatures that we can perceive their agreement with the cœlenterate plan of organization.

Coral

7. Coral reefs, produced by Anthozoa living in vast groups, are of great interest and importance to geographers and geologists. Innumerable islands of the

Pacific Ocean are composed wholly of coral, and the great barrier reef of Australia is also coralline. Many rocks consist of fossil coral; thus a fossil coral reef may be seen at Beulah, New Mexico, now 8000 feet above the level of the sea. Charles Darwin, during the voyage of the *Beagle*, studied the formation of coral reefs, and concluded that the circular coral islands represented volcanic peaks or masses of rock which had disappeared beneath the waves, leaving the surrounding coral to grow upward in circular form. The coral animals do best where the surf breaks on them, the water being abundantly supplied with oxygen, and hence they tend to grow most on the outer side of the reef. Were the reef to subside suddenly, the animals would perish; but the subsidence has been so slow that they have kept pace with it, building always on the skeletons of their ancestors. The wash of the waves has piled up masses of dead coral, with the result of forming a beach a little above sea level, on which coconut palms and other vegetation may grow. Professor W. M. Davis of Harvard University recently visited the South Seas to study this matter afresh, and was able to confirm Darwin's theory. It must be said, however, that there are various kinds of reefs, and some of them are largely due to lime-secreting algæ or seaweeds.

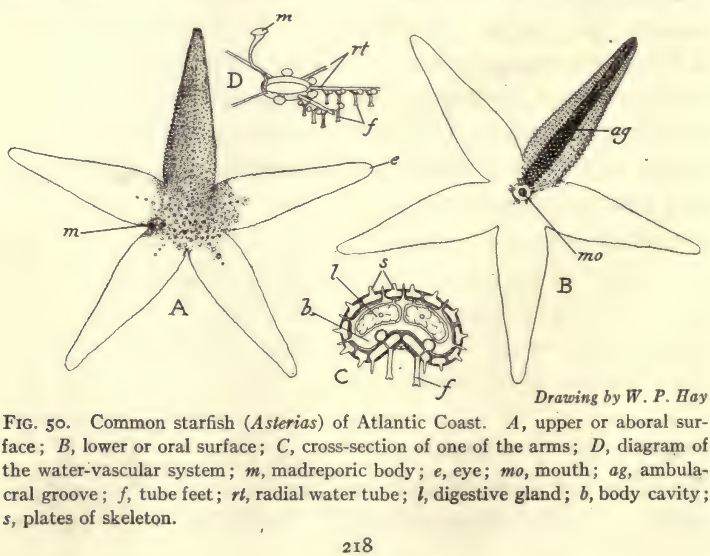
Darwin's observations

CHAPTER TWENTY-NINE

ECHINODERMATA

Origin and characters of Echinodermata

1. THE origin of the Echinodermata is problematical, but they are certainly much less primitive than the Cœlenterata. The larva is more or less wormlike or curiously branched, with a distinct bilateral symmetry. There seems to be a certain relationship with the Cirripedia or barnacles, and therefore with the Arthropoda. However this may be, the phylum is one of the most distinct and easily recognized, though its different members are very diverse. They inhabit the sea, although one of the wormlike sea cucumbers (Synapta) may be found in brackish water in mangrove swamps. The adult animals are usually recognizable by their radial symmetry, with a calcareous outer skeleton; internally we find a complete alimentary canal, with two openings, and a body cavity between this and the outer wall. The nervous system is closely connected with the skin, and there



Drawing by W. P. Hay

FIG. 50. Common starfish (*Asterias*) of Atlantic Coast. *A*, upper or aboral surface; *B*, lower or oral surface; *C*, cross-section of one of the arms; *D*, diagram of the water-vascular system; ***m***, madreporic body; ***e***, eye; ***mo***, mouth; ***ag***, ambulacral groove; *f*, tube feet; ***rt***, radial water tube; ***l***, digestive gland; ***b***, body cavity; ***s***, plates of skeleton.

is no brain. There is no heart or definite system of blood vessels. There is, however, a remarkable *water-vascular system*, which consists of a series of tubes connected with tube feet or podia, especially conspicuous in the starfish, where they serve for locomotion. In a starfish or sea urchin a sievelike plate (madreporite) may be found on the upper (aboral) surface. Through this water passes into a canal, propelled by movements of minute cilia. This canal or tube ends in a tubular ring, from which proceed radially five tubes, following the arms of the starfish, or ascending within the sides of the sea urchin. Extending from these radial tubes are small, hollow processes, the tube feet. The structure is somewhat more complicated than this brief description would suggest, and of course differs in detail in different groups, but the fundamental pattern is that just outlined. In the wormlike sea cucumbers the canals are present in the young, but lost in the adult. The sea urchin was studied ages ago by Aristotle, and because of its spiny surface he called it *Echinus*, or hedgehog. This name is still used for the animal, and has become the basis of the name of the phylum, Echinodermata meaning "hedgehog-skinned" or "spiny-skinned." Aristotle observed that the mouth and gullet of the sea urchin (on the lower surface) are surrounded by a series of elongated pointed plates, which serve for mastication. The whole structure resembles a lantern, and is often called "Aristotle's lantern." Reproduction is sexual, but arms of starfishes, if removed with a portion of the disk, will develop into whole animals.

Water-vascular system

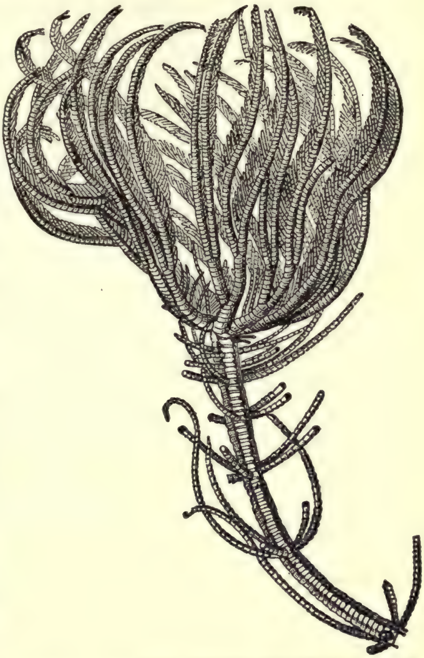
Aristotle's lantern

Psychology of the starfish

2. Attempts have been made to understand the psychology of echinoderms. Professor Jennings, working on the coast of California, made many experiments with the common starfish of that region. The animal

readily responds to direct stimuli, of course, but is it capable of utilizing its past experiences? When a starfish is turned on its back, it feels uncomfortable, or acts as if it felt so. With its arms it tries to take hold of some neighboring object and turn over. Obviously if all five arms acted at once, they would counteract one another, and the animal would remain in the reversed position. Hence as soon as one arm has a good hold, the others cease to oppose it, and success results. When the surface is flat, it is a matter of chance which arm initiates the work. Now Professor Jennings conceived the idea of holding down four of the five arms, and causing a given starfish repeatedly to use a particular member in the act of righting itself. After repeated lessons, he found that the animals would continue for a time to use this arm in preference to the others, even when not interfered with. Thus it seemed to have memory, though the education of starfishes is an expensive business, requiring a separate tutor for each individual and the repetition of the whole course about once a week. Critics suggested that after all there was perhaps no true educational process, but that the impeded arms were slightly injured or stiffened, or suffered from lack of exercise, giving the active one a better chance. Whether the starfish remembers or not, it is a persevering animal. It can open clamshells by sheer persistence, although in a single pull the mollusk is the stronger. The starfish envelops the shell, and the poor mollusk, striving to save its life, exerts its adductor muscles to the utmost, shutting the valves "as tight as a clam." It has been calculated that the starfish can exert a pull equivalent to 1350 grams, but the mollusk can resist one of 4000 grams. However, the starfish has more "staying power," and tires out its prey, which finally has to succumb.

3. The echinoderms may be divided into three subphyla, called *Pelmatozoa*, *Asterozoa*, and *Echinozoa*. **Divisions of Echinodermata** The Pelmatozoa include the cystoids, blastoids, and crinoids, but only the last of these divisions is living today. The other two disappeared before the end of Palæozoic time, but were important groups in their day. The Pelmatozoa are fixed, usually with a distinct stalk, on the aboral surface, and consequently the mouth is directed upward. Exceptions to this statement are found, however, in the adults of many crinoids,



From Perrier's "Traité de Zoologie"

FIG. 51. Isocrinus (or Pentacrinus) asteria.

which are wholly free, and might easily be confused with starfishes. The word crinoid means "like a lily" **Crinoids or sea lilies** and has been given because of the long-stalked forms, with the so-called calyx and feathery arms at the summit, resembling flowering plants. The crinoids were dominant during the Palæozoic, producing innumerable genera and species, often of large size and complex form. A wonderful slab of fossil crinoids (Scyphocrinites) may be seen in the United States National Museum. These existed during a period when much of the interior of North America, east of the Rocky Mountains, was cov-

ered by a shallow sea, an American Mediterranean. In these waters crinoids existed in vast numbers, and their remains may be found in the rocks over a large part of the country. When this sea was drained, during the Mesozoic, the crinoids mostly died out, leaving comparatively few representatives. In more modern times many genera and species of crinoids have come into existence, but they mostly show little resemblance to those of remote antiquity, and there is no reason to suppose that the group will ever again recover its ancient glory.

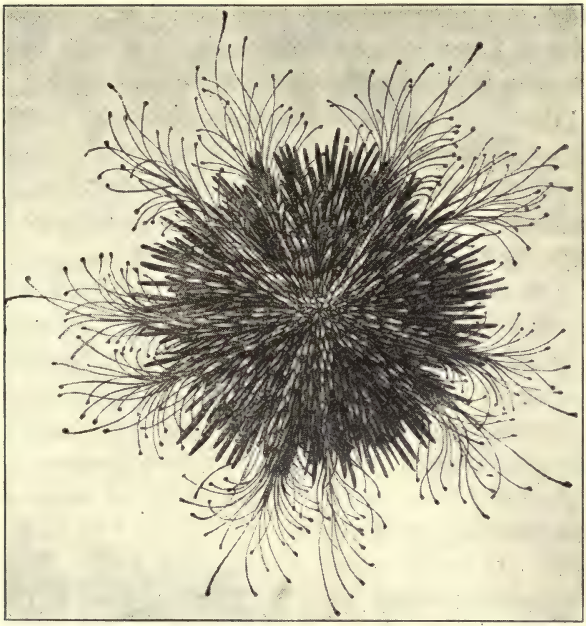
Starfish

4. The Asterozoa, or star animals (Greek, *aster*, a star, from which our English word is little modified), include the starfishes and brittle stars. There are very important differences between these groups, although both have the starlike form, with arms extending from a central disk. In the *Asteroidea* or true starfishes, the arms are usually five, but may be much more numerous; they are not sharply marked off from the central disk. The arms present on the under surface *ambulacral grooves*, with podia (singular, *podium*) or tube feet. In

Brittle stars

the *Ophiuroidea* (snakelike animals) or brittle stars there is a round central disk, with long, wormlike arms which curl around objects presented to them. The ambulacral grooves are closed, and the podia have only sensory and respiratory functions. The arms readily snap off, whence the name brittle star. In the ophiuroids the madreporite is on the oral side of the disk. Although the asteroids and ophiuroids are so easily distinguished, there is a group called Lysophiuroida, found in the Palæozoic rocks of Europe, which is more or less intermediate between the two, indicating that they had a common ancestor.

5. The Echinozoa include also two extremely distinct groups, the *Echinoidea* or sea urchins, and the *Holothu-*



From "Animate Creation"

FIG. 52. A sea urchin, showing spines and extended podia.

roidea or sea cucumbers. They agree in being without arms or stalk, but their superficial appearance would not suggest any affinity. The sea urchin is variously rounded or oval, conical or flattened, with a hard surface to which are attached numerous spines. These spines may be clubbed, exceedingly large, and thick, or they may be very slender, sharp, and needlelike. There are also very peculiar structures known as *pedicellariæ*, which may likewise be found on starfishes. They appear to be modified spines, but have the form of a little stem, on the end of which are two or three pincer-like valves, which open and shut. These pedicellariæ differ in form and function. Some grasp and destroy minute swimming larvæ of animals which might settle on the

Sea urchins

Echinus. Others break up particles of grit, while some hold small Crustacea and other animals until the tube feet can reach them and pass them to the mouth. Some have poison glands, and serve to repel the attacks of enemies. The common California sand dollar is a very flat echinoid, adapted, as are the flatfishes, for life on sandy bottoms, where they offer little resistance to the currents or tidal movements of the water.

Sea cucumbers

6. The *Holothuroidea*, shaped like a cucumber or a worm, at first present no resemblance to the echinoids. If we imagine an echinoid to be soft, and to be elongated by pulling at the oral and aboral ends, it will assume a form resembling that of a holothurian. Instead of having a hard shell, the sea cucumbers possess only an imperfect skeleton, usually in the form of minute spicules, reminding us of the sponges. In some cases the skeletal elements are entirely absent. It is difficult to preserve good specimens of holothurians, because of their behavior when irritated. Sometimes they turn inside out, or rather extrude the internal organs of the body.

The Cuvierian organs

The first parts extruded are the Cuvierian organs (part of the respiratory apparatus), which form a tangle of sticky white thread, enveloping and rendering helpless any creature

From Perrier

FIG. 53. A sea cucumber.

which has had the temerity to attack the holothurian. A large lobster has been seen thus ensnared, and quite unable to move. It might be supposed that this mode of defense would be fatal to the sea cucumber, but that animal merely goes into retirement for a time, and regenerates the lost parts.

The wormlike species (*Synapta*) behave differently. The posterior part of the body is amputated, while the head with its feelers buries itself in the sand or mud. The Echinodermata, whatever their origin, have themselves given rise to no other groups. They represent a separate branch of the tree of life, as do the sponges and mollusks.

CHAPTER THIRTY

BRYOZOA

Characters of Bryozoa

1. THE *Bryozoa* (the term meaning "moss animals") are small aquatic creatures, mostly marine, nearly

From "Animate Creation"

FIG. 54. Bryozoans, *Plumatella*, from fresh water. The upper figure greatly enlarged.

always living in colonies or *zoaria*, often looking very much like seaweeds or corals. Each separate individual (zoöid) is placed in a membranous or calcareous (limy) sac, called the zoöecium. They differ entirely from coral animals in possessing an alimentary canal with two openings, and a well-developed nervous system, distinct body cavity, etc. The mouth is surrounded by delicate respiratory tentacles. The colonies are formed by gemmation or budding, but the animals have sexual organs, being usually hermaphroditic. There is no heart or true blood system.

The Bryozoa are of great antiquity, and are abun-

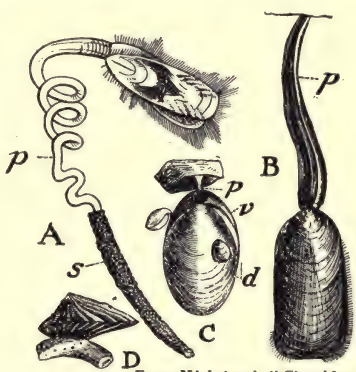
dantly preserved as fossils. Like the much more primitive sponges, they represent an isolated type, which has produced a great number of genera and species, without showing much real progress.

Antiquity of the group

BRACHIOPODA

Structure of Brachiopoda

1. The nearest relatives of the Bryozoa are the so-called lampshells or *Brachiopoda*. They are exclusively marine, and today are relatively rare, fewer than 200 species being known. In Palæozoic times they were extremely numerous, and thousands of forms have been made known from the fossil remains. The name "lampshell" is derived from the fact that in typical forms the bivalved shell, more or less oval in form, shows an opening at one end for the pedicel by which the animal is attached to a rock or some other solid object. The shell consequently resembles a Roman lamp, such as those recovered at Pompeii, the opening corresponding to that for the wick. For many years the Brachiopoda were classified as mollusks, but the most superficial examination of the internal organs shows that this is entirely erroneous. On opening the shell we find the variously coiled or twisted *brachidia*, which support the brachia or fleshy arms; the latter possess a respiratory function, and also set up currents of water which serve



From Nicholson's "Classification of the Animal Kingdom"

FIG. 55. Brachiopods. *A*, *B*, Lingula; *C*, Waldheimia; *D*, Isocrania. *p*, peduncle; *v*, ventral valve; *d*, dorsal valve; *s*, sand particles inclosing end of peduncle.

to convey small particles of food to the mouth. These structures are fully developed in the typical lampshells, but are variously modified in other families. The sexes in the Brachiopoda are separate.

Lingula, an ancient type still surviving

The burrowing species, typified by *Lingula*, are oblong and flattened, with thin shells, and have a long, worm-like pedicel. Living specimens may be obtained on the California and southern Atlantic coasts, and extremely similar shells come from the older Palæozoic rocks. We thus think of the *Lingula* as one of the oldest of all living creatures, little changed during many millions of years.

CHAPTER THIRTY-ONE

PLATYHELMINTHES

The Vermes or worms of early writers

1. It was formerly customary to include under the name *Vermes* [1] a great variety of different organisms, roughly classed as worms. These did not, of course, include the so-called worms which are the larvæ of insects, but they did include such creatures as rotifers, which would not usually be thought of as worms at all. It could be said of the Vermes that they were bilaterally symmetrical, usually greatly elongated or "vermiform," with a distinct body cavity between the intestine and outer wall. They could thus be excluded from the cœlenterates and echinoderms, while the absence of distinct jointed appendages served to indicate that they were not Arthropods. In recent works these Vermes or Vermidea have been divided, so that today we recognize flatworms, nemertines, threadworms, rotifers, and annelids, forming a series of phyla. The flatworms are called *Platyhelminthes*, which is an exact Greek translation of the English term. The Greek word for a worm appears in many other combinations, and a student of worms calls himself a helminthologist, while a society for the study of worms is a helminthological society.

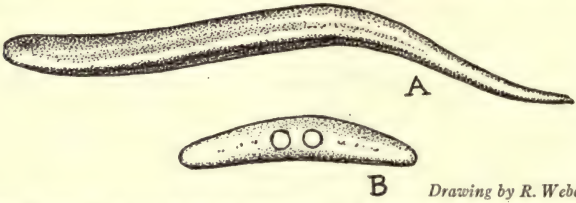
Flatworms

Groups of flatworms

The flatworms, as the name suggests, are more or less flat and usually ribbonlike. They are usually divided into three classes, the *Turbellaria*, *Trematoda*, and *Cestoda;* but a fourth division is indicated by a group of peculiar animals living on the outer surface of freshwater Crustacea, turtles, etc., to which the name *Temnocephaloidea* has been given. The *Turbellaria* or plana-

[1] Our word "worms" is a strict equivalent. There is no "W" in Latin: thus the Latin *vallum* is our "wall."

rians are free-living flatworms, with ciliated skin, having the alimentary canal in the form of a blind sac,



Drawing by R. Weber

FIG. 56. A land planarian from Guatemala. *A*, about twice natural size; *B*, a cross section of hinder part of body much enlarged, showing the two posterior branches of the intestine.

— that is, with only one opening, — which may be simple or variously lobed. On account of the form of the intestine, there is a certain resemblance to the Cœlenterata, but it is superficial, and does not extend to other parts of the anatomy. Turbellarians exist in the sea in great numbers, and are fairly numerous in fresh water. A small, dark species may often be found in mountain springs. There are also many land species, looking something like slugs, living in regions where the climate is moist. A large form has become established in hothouses. Some of the species are quite large and brightly colored; others, such as the fresh-water Rhabdocœlida, are microscopical and transparent, looking like Protozoa, but easily distinguished by the complexity of their anatomy.

Land and fresh-water flatworms

Parasitic flatworms

3. The *Trematoda* include the parasitic worms known as flukes. They possess an alimentary canal, but have lost the ciliation of the body surface, and have developed suckers or adhesive organs. There is no doubt that they arose from free-living ancestors, and are modified for parasitic life. Throughout the Vermidea we find many instances of such modification, taking place quite independently in the different groups. We can no more

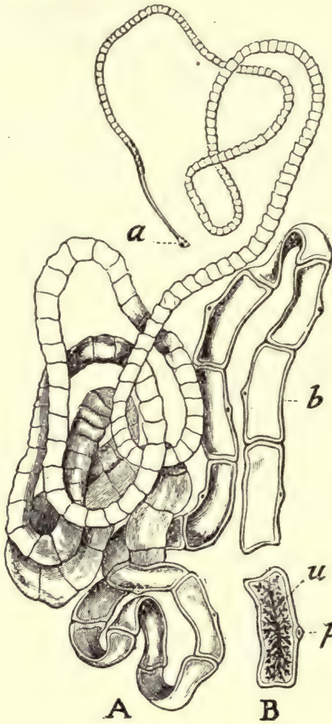
put the parasitic worms together, because of their parasitism, than we could unite in one group of plants the parasitic rust fungi and the mistletoe. The destructive liver fluke of the sheep may be taken as an example of this group. It lives in its early stages in a small fresh-water snail (*Lymnæa*), common in Europe and America. The young flukes, known as *cercariæ*, eventually leave the snails and attach themselves to the grass at the edge of the pond, where grass and worms are eaten together by the sheep. In the body of the sheep they seek the liver, where they develop to full size. Eggs are produced, which become scattered over the pastures, and when they hatch, the snails, if present, become infested. It used to be estimated that a million sheep died annually in the British Islands from the attacks of the liver fluke, but now that the life history is known, it is comparatively easy to guard against infestation. The European liver fluke is not native in America, but has been introduced unintentionally by man. There is, however, a large native American species.

The liver fluke

4. The cestodes, or tapeworms, represent the most extreme specialization for parasitic life among flatworms. They are flat and white, resembling tape, but usually segmented. The alimentary canal is wholly absent, even in the early stages. The unsegmented tapeworms are rarely observed; and we may take the common segmented forms, such as *Tænia*, as typical of the group. In these the adult worm possesses a so-called head, which produces no eggs, but carries the organs which fix the animal to the intestine of the host. Following the head are numerous segments or *proglottids*, which are egg-producing, and usually drop off from time to time when mature. The segmentation is

Tapeworms

entirely different from that of an annelid or arthropod, in which the successive segments carry different organs and together make up a single animal of which they are the necessary parts. In the tapeworm the segments in a sense represent different individuals, attached but not combining to form parts of a single machine. Each segment takes nourishment independently, through the skin, and each one produces eggs when mature, excepting only the "head" or *scolex*.



From Nicholson's "Classification of the Animal Kingdom"

FIG. 57. A tapeworm, *Tænia solium*: *a*, head; *b*, a proglottid; *B*, a single proglottid detached; *p*, genital pore; *u*, uterus.

Life history of the tapeworm

The eggs give rise to a hooked embryo (or in some species to a ciliated larva), which seeks the proper host and develops into a bladder worm or *Cysticercus*. The host of the *Cysticercus* is usually eaten by the final host, in the body of which the mature tapeworms develop. The invention of cooking by man not only made many substances palatable and digestible, but was of great importance as a means of destroying the young stages of parasitic worms, which would otherwise be eaten alive.

CHAPTER THIRTY-TWO

NEMERTINEA

Characters and habits of nemerteans

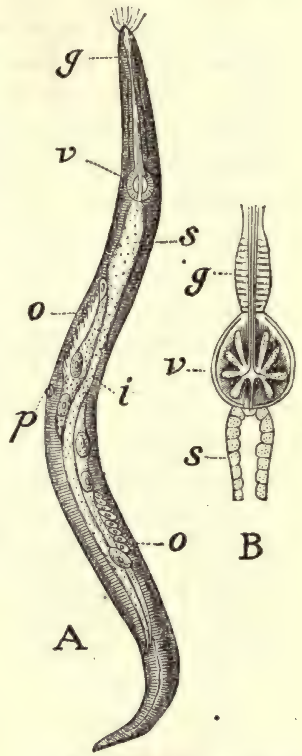
1. The nemertean worms are little known to the general public, as they are of slight economic importance. They mostly live in the sea, burrowing in mud or sand, or hiding under stones and among the holdfasts of large seaweeds. Fresh-water and even land forms have been found, the latter living in moist earth or decaying vegetable matter. There are even a few parasitic or semiparasitic forms, though nemerteans in general live independently. The great majority are long and more or less cylindrical, and, as in the Turbellaria, the skin is ciliated and the body is unsegmented. There is, indeed, much resemblance to the flatworms, but the alimentary canal has two openings (as in all the higher worms) instead of one. The mouth is furnished with a remarkable proboscis which is capable of being everted. The sexes are usually separate, whereas the flatworms are hermaphroditic, with very few exceptions. Some of the marine species attain extraordinary lengths; the threadlike *Lineus* is said to reach a length of 27 meters. Others are beautifully colored, — bright red, orange, or pink, or purplish with white cross lines. They are carnivorous, attacking any animals which are not too large.

NEMATHELMINTHES

Structure of threadworms

1. The *Nemathelminthes* are the threadworms; the scientific name is only the English one in Greek. They have the usual wormlike shape, — cylindrical, not flat, and without visible segmentation. The group in general is parasitic, but small forms may be found com-

monly in water or damp earth. They are not ciliate. The sexes are almost invariably separate. They are divided into the *Nematoda* or nematodes; the *Nematomorpha*, which include the hairlike *Gordius;* and the *Acanthocephala*, a group of curious parasites having recurved hooks on the proboscis.



From Nicholson's "Classification of the Animal Kingdom"

FIG. 58. A nematode worm (*Rhabditis bioculata*), female, enlarged. *g*, gullet; *v*, muscular gizzard; *s*, stomach; *i*, intestine; *o*, ovary; *p*, genital pore.

Habits and abundance of threadworms

The nematodes, or typical threadworms, exist in the greatest variety and abundance. They are parasitic on animals and plants, many of them infesting man. Although the parasitic forms are best known, Dr. M. A. Cobb, who has paid special attention to the subject, believes that the free-living ones, when fully described, will prove even more numerous. He states that the nematodes in a 10-acre field, if arranged in single file, would form a procession long enough to reach around the world.

Parasitic threadworms

To give some idea of the numbers occurring as parasites, we may cite the case of a young horse in which were found 500 *Ascaris*, 190 *Oxyuris*, several millions of *Strongylus*, 214 *Sclerostomum*, and 287 *Filaria*, not to mention a quantity of tapeworms. Some of the

diseases produced by these animals are extremely serious. Trichinosis is due to infestation by the small nematode *Trichinella*, which we get through eating infested pork which has not been sufficiently cooked. The notorious hookworm of the Southern states is also a nematode.[1] So also is the African Guinea worm, which lives first in a minute fresh-water crustacean (Cyclops), and is swallowed by man in drinking water. Another species infests man and the mosquito alternately. A nematode, attacking the roots of plants, produces swellings or galls. Another is very injurious to the sugar beet.

The structure of nematodes is quite complicated, so that Dr. Cobb, in making a diagram of the anatomy, is able to enumerate no less than 116 distinct parts. Fortunately the small species are transparent, so that the various organs can be seen in the living animal.

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ROTATORIA

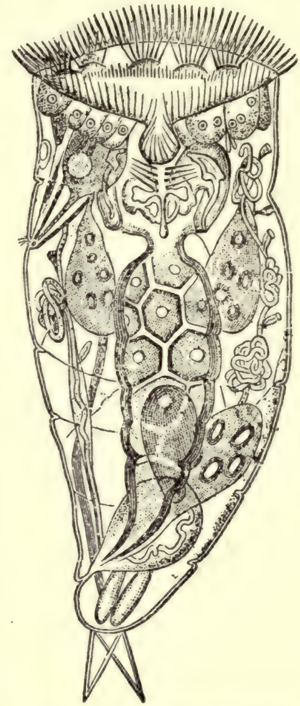
Structure of a rotifer

1. The Rotatoria, or rotifers, are minute aquatic animals which may be taken for Protozoa, unless attention is paid to their anatomy. They seem to have "wheels in their heads," owing to the presence of constantly moving cilia arranged in a circle around the anterior end. As they are usually quite transparent, it is easy to see the chitinous gizzard or *mastax*, the alimentary canal, reproductive organs, etc. The common free-swimming forms have a short bifurcated or two-

[1] See the publications of the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease.

toed tail, but there are species (as *Melicerta*) which are attached and surrounded by a tube. These tubes stand on end, projecting at right angles to the surface to which they adhere. Rotifers are most abundant in fresh water, but rather numerous species occur in the sea. Some aberrant genera are parasitic. A remarkable property of rotifers is that of resisting desiccation; as the water in which they live dries, they secrete gelatinous plugs at either end of the body and are thus protected within their own skins, where they can resist great extremes of temperature as well as dryness. This property enables them to survive the most untoward circumstances, and to be carried accidentally from place to place, with the result that the species are extremely widely distributed.

Habits and distribution of rotifers



From Perrier's "Traité de Zoologie"

Fig. 59. A rotifer, *Hydatina senta*, female; greatly enlarged.

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CHAPTER THIRTY-THREE

ANNELID WORMS

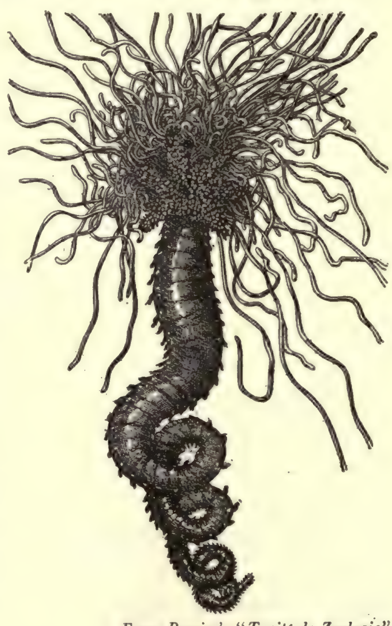
1. THE higher worms are distinguished by the segmentation of the body (into annuli or rings) and, except in leeches, by the presence of bristles which can be used in locomotion. Thus, an earthworm appears perfectly smooth, but pass the fingers along the sides, and it feels rough. Examination with a lens reveals little projecting points, which give the worm a hold on the walls of its burrow, recalling the spiked shoes of the telephone company's "trouble man." These bristles or spinelike structures are called "chætæ," and hence the great group so common in the sea, distinguished by the abundance and length of the chætæ, is called *Polychæta* (many bristles). In contrast with them, the earthworms and their relatives are called *Oligochæta* (few bristles). While these are the two main groups of annelids, we must associate with them a third important group, the *Hirudinea* or leeches. These may be recognized by the flattened under side and the presence of an adhesive disk or *sucker*, at each end of the body. There is also a small group called *Archiannelida*, the members of which have rings of cilia around the body, but no bristles, and when adult are not visibly segmented. As in so many other cases, the place of these animals in the classification is determined by the totality of their characters, and would not be suspected on superficial examination. **Structure of the annelid worms**

2. The ringed worms are not only interesting in themselves, but also on account of their apparent affinity with the *Arthropoda*, the great group which includes the insects and Crustacea. First of all we have the segmentation of the body, so characteristic of **Resemblances to arthropods**

arthropods. Then there are the bristles, often placed (as in the marine *Nereis*) on lobelike outgrowths which resemble rudimentary legs. The head, though without antennæ, may be provided with long tentacles, and we can often recognize jaws which are very like those of an insect. Thus we have an animal which satisfies in a general way the requirements of an ancestor of the arthropods, foreshadowing their characters, though not of them. The comparatively low organization is shown by the fact that many marine worms retain the method of reproduction by constriction or budding, forming a series of individuals joined at the ends, like a string of sausages, ultimately coming apart. This goes with true sexual reproduction, as we have found in the lower groups.

The Polychaete or many-bristled worms

3. Polychæte worms are aquatic, and although a few species live in fresh water, the sea is the habitat of the vast majority of the species. Some are free swimming, others make tubes, often reminding us of those constructed by insect larvæ. Many are beautifully colored, and this ornamentation may be due to different causes. Sometimes the bristles densely covering part of the body are splendidly iridescent. In other cases the red,



From Perrier's "Traité de Zoologie"

FIG. 60. A Polychæte worm, *Amphitrite edwardsii;* about $\frac{2}{3}$ natural size.

yellow, violet, green, or other tint may be due entirely to pigments in or under the skin. Red may be due to hæmoglobin in the blood, the substance which also makes our blood red. The worm is so transparent that the full red color of the blood shines through the skin. This case is interesting in reference to the question whether the bright colors of many marine worms have any useful purpose. Obviously hæmoglobin has a function in relation to respiration, and its red color may have no particular significance as such. Did we not know the physiological significance of hæmoglobin, we might be puzzled to offer any reason for the bright color of the worm. The tubes of Polychæta have as a basis a secretion of the worms themselves, but frequently particles of sand or fragments of shell are built in, much as in the case of the tubes made by caddis-fly larvæ (page 273). The *Serpulidæ* make calcareous (limy) shells, suggestive of those made by mollusks. This resemblance is particularly striking in the genus *Spirorbis*, the small tube shells of which are coiled like a snail. The coiled shells of *Spirorbis* adhere to various objects, and as they are hard they are easily preserved as fossils. In strata many millions of years old, these small structures are found, apparently as well developed as those of today.

Polychæte gills are interesting structures, finely branched, with the form of seaweed or feathers. Aquatic insect larvæ often show gills of various forms, having the same function of absorbing oxygen from the water.

4. The oligochætes do not all live in the earth; many inhabit fresh water. Thus the polychætes and oligochætes divide the world between them, and there are few places where one or the other may not be found. Strangely, true earthworms appear to have been absent **Earthworms**

from or excessively rare in the Rocky Mountain region; those found there today are cosmopolitan species introduced by man, excepting a small form from the mountains of Colorado. Generally speaking, the ocean is a barrier to earthworms, and hence these, like amphibians, are absent from oceanic islands, except when introduced by human agencies. When islands are found to possess many peculiar earthworms, we infer that they were once united with the nearest continent.

Darwin's experiments with earthworms

The importance of earthworms to mankind has been shown by Charles Darwin and others. In moist countries the ground may be seen to be almost covered with their castings after a shower. They burrow through the soil, and bring that which was below to the surface. Darwin allowed a field to remain uncultivated for many years, to see how soon and how deeply the worms would bury objects originally left on the surface. The burying process is simply one of turning over the soil, whereby the original surface is covered by material from beneath, and eventually sinks. In this manner the soil is subjected to the action of the bacteria which work in the presence of oxygen and, breaking up insoluble chemical compounds, render the materials in it fit for plant food.

Structure of earthworms

5. The so-called cocoons of earthworms are really egg cases. They are oval or round objects composed of chitin, containing several eggs. The oligochætes are hermaphroditic, possessing both male and female organs, though these frequently mature at different times. The alimentary canal is a straight tube running through the body, not affected by the segmentation. Earthworms have no distinct organs of vision, but appear to be sensitive to light. Although they cannot hear, they readily appreciate vibrations in the soil. Unlike the

polychætes, the oligochætes are, generally speaking, without gills, though these structures are developed in a few fresh-water forms. There are no jaws, except in a peculiar group which is parasitic on crayfishes and has no close resemblance to the earthworms.

Leeches

6. Leeches (*Hirudinea*) are usually found in fresh water, where they swim with an undulating motion. In moist regions land leeches may be found, and there are even marine species. The medicinal leech (*Hirudo medicinalis*), formerly used to draw blood, possesses jaws. Other leeches have a proboscis, but are without jaws. The Hirudinea resemble the earthworms in the segmented body, and also in the egg cocoon, which may be found attached to plants or rocks in ponds. With one exception chætæ are absent, and this separates them from all the oligochætes except a few aberrant types. There are some species with external gills. Simple eyes are present.

Lines of modification in annelids

We may infer that of the three great groups of annelids, the polychætes are the most primitive, in spite of the fact that they include many specialized forms. The leeches and earthworms are related, but represent widely divergent branches of a common stock, — both, however, adapted to fresh-water and terrestrial existence. Of these, no doubt the oldest are fresh-water forms. The earthworms have lost the jaws, the leeches the chætæ; hence it is impossible to derive either group from the other.

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CHAPTER THIRTY-FOUR

MOLLUSCA

Characters of Mollusca

1. The Mollusca include such familiar animals as the snails and slugs, cuttlefish, oysters, and clams. They are soft-bodied, without the chitinous external armor of the Arthropoda. The majority of the species possess a shell, which is secreted by the animal, and consists principally of carbonate of lime. The alimentary canal, blood system (with a simple heart), respiratory system (lung or gills), and liver are well developed, and eyes are usually present. Some feed on vegetable matter, others are carnivorous. The number of known species is very great, and as the shells are readily preserved as fossils, mollusks are of great importance to the geologist. In the course of time the groups of mollusks have become variously modified and consequently their fossil remains serve as excellent guides to the strata, each considerable layer of rocks having its own characteristic assemblage.

Importance for geology

Groups of Mollusca

2. The larger groups of mollusks are so different that at first they seem to have little in common. Compare, for instance, a snail with a clam or an octopus. There is, however, a certain similarity of structure which leads us to place them all in a single phylum, and sometimes very different-looking forms are found to be connected by intermediates. Thus the snail and the slug, although very distinct, are merely the extremes of a series of species in which the shell is of all sizes, grading from the larger one of the typical snail to the rudimentary or hidden one of the slug. Finally, in some slugs, not even a rudiment of the shell remains. The large group called *Gastropoda* (literally stomach-footed) includes the ordinary coiled shells — terrestrial, fresh-water, and marine — and the naked slugs. If we examine an ordinary

After Bulletin American Museum of Natural History

FIG. 61. *Pyramidula ralstonensis*, a fossil snail from the Eocene of Wyoming. Enlarged about five diameters.

Structure of a snail

garden or greenhouse snail, we observe that the body, when extruded from the shell, is elongated, with the head at one end. There is always, of course, a portion of the animal within the shell. The flat surface on which the animal moves is called the *foot*, and the movement is by wavelike undulations, as can be seen if the snail is caused to walk on a piece of glass. It is difficult at first to believe that the substance of the foot is not flowing from one end to the other, just as waves on the ocean give the appearance of masses of water moving rapidly forward. As the snail moves, slime is secreted by the *slime glands*, and thus the creature travels on a track of its own laying. The head is marked by four tentacles, the upper long ones bearing eyes at the end. These eye-bearing tentacles can be retracted by the contraction of internal muscles; they turn outside in, as do the fingers of a hastily removed glove. Below the

Jaw and lingual membrane

tentacles is the mouth, which is furnished with a transversely placed chitinous plate called the *jaw*. The jaw moves up and down, and cuts the tissue of plants. In certain carnivorous slugs, which devour their prey alive, there is no jaw. In addition to the jaw is a delicate rasping structure, the *lingual membrane*. This

may be obtained by cutting off the head of the snail and boiling it in caustic potash solution, which dissolves away everything except the jaw and lingual membrane. The surface of the membrane, examined under the compound microscope, is seen to be covered with innumerable delicate teeth, arranged in rows. These teeth are different in different kinds of mollusks, and are of great value for classification. Around the edge of the shell, in front, will be seen a soft fold, which is the margin of the *mantle*. This is the organ which secretes the shell, adding always material around the aperture, until the animal is mature, when the work is usually finished by addition of a thickened edge, the *lip*. On the right-hand side, when the snail is active, there appears an opening, which admits air to the lung. The lung is a simple moist sac, the walls of which are richly supplied with blood vessels. The lung-breathing snails are called *pulmonates*, and include many terrestrial and

Breathing apparatus

From "Animate Creation"

FIG. 62. A large African land snail, *Achatina*, about natural size.

fresh-water forms, but the majority of marine species are gill breathers. Thus the land slugs have lungs,

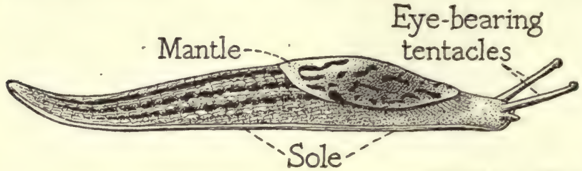


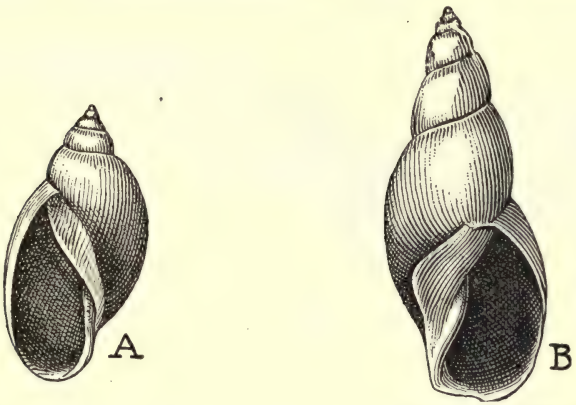
FIG. 63. A land slug (*Limax*). Natural size.

situated beneath the mantle; but the sea slugs (*nudibranchs*) are very different, and possess external feather-like gills. The lung-breathing aquatic mollusks, including the commoner pond snails, have evidently been derived from land-inhabiting ancestors. With rare exceptions they have to come to the surface of the water to take in air.

Shell of the snail

3. The snail's shell, from which the principal characters for the description of the species are derived, is nearly always very distinctive. Many kinds of mollusks are known from the shell alone, yet we have no difficulty in recognizing them. The commoner form of shell is more or less conical, the upper end being called the *apex*, the lower side the *base*. It is composed of *whorls*, twisting around a central *axis*, which may be hollow and open below, the opening being called the *umbilicus*. The whorls are attached to each other along a spiral line called the *suture;* the surface of a whorl may be rounded or keeled, or may have raised lines. The aperture of the shell, commonly called the *mouth*, has of course no connection with the true mouth of the animal. The mouth may be surrounded by a thickening called the *lip*, and on this are often denticles or *lamellæ*. The shells of land and fresh-water mollusks are usually thinner and lighter than those found in the

sea. The marine forms, moving in a relatively dense medium, can afford to have thick shells, and in addition



Drawing by R. Weber

FIG. 64. Freshwater Mollusca (enlarged). *A*, a sinistral shell (*Physa*). *B*, a dextral shell (*Lymnæa*).

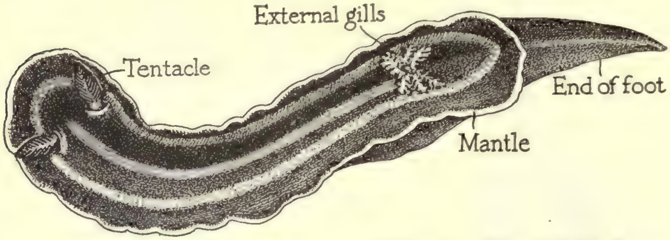
Dextral and sinistral shells

they need to be protected from the buffeting of the waves if they live near the shore. Most snail shells have what is called a *dextral* spiral; that is, if the shell is held so that the aperture faces the observer, it is on the right-hand side. *Sinistral* shells have the aperture to the left, the whole spiral being reversed. Certain genera, as the fresh-water *Physa*, are regularly sinistral. Very rarely sinistral specimens of ordinarily dextral species are found; these are much prized by collectors of shells. The reversal of the normal twist, as a rare abnormality, is not confined to mollusks; even in man the heart is occasionally on the right instead of the left side.

Sea slugs

Some marine shells, such as the *Murex*, are protected by great spinelike projections. Even the sea slugs, naked and apparently without any resource against enemies, have special means of protection. Some are

colored olive-brown or red, exactly like the seaweeds on which they live; others (*Chromodoris*) are extremely



Drawing by R. Weber (after MacFarland)

FIG. 65. Sea slug or nudibranch (*Chromodoris porteræ*) from the coast of California; showing warning coloration. It is bright ultramarine blue, with the band along each side of the mantle bright orange (enlarged).

conspicuous, with purple or blue and orange colors. These latter secrete substances which make them distasteful, and it is supposed that they possess "warning coloration," enabling fishes to recognize them and let them alone. Many of the gill-breathing Gastropoda, especially those living in the sea, possess a circular shelly or horny plate, the *operculum*, with which they close the mouth of the shell when alarmed. When the animal is in motion the operculum is seen attached to the outer surface of the body, held somewhat as the shield of a marching Roman soldier.

Chitons

4. The *Amphineura*, formerly classed with the Gastropoda, include the *Chitons*, a marine group which has no spiral shell and looks as much like a crustacean as like a mollusk. The body is flat and usually broad, and on the upper surface are eight transverse shelly plates, giving a false appearance of segmentation. The creature is bilaterally symmetrical, without any of the torsion so characteristic of the snails. In many cases the shell valves bear minute eyes, which may number many thousands in a single individual. Related to the chitons

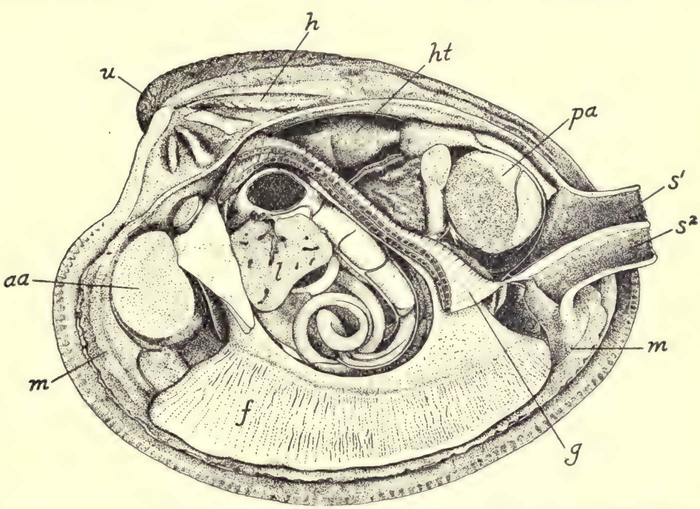
is a curious wormlike group without any shell, which may be considered the slugs of this series. Chitons are common on rocks between tide marks on our Atlantic and Pacific coasts; some of the Californian species are quite large, one being about 9 inches in length. Another bilaterally symmetrical group of mollusks is the *Scaphopoda*, including the *Dentalium* or tooth shell. The shell is a long, cylindrical tube, tapering apically. These are all marine.

The Scaphopoda or tooth shells

5. The *Lamellibranchiata* or leaf-gilled mollusks are also called *Pelecypoda* (hatchet-footed). They are the bivalves, with two similar parts to the shell; familiar examples are the oyster, clam, mussel, and cockle. They differ from the Gastropoda in many very important characters; there is no well-defined head, and the

Bivalve Mollusca

Structure of a bivalve



Drawing by W. P. Hay (after model in Am. Mus. Natural History)

FIG. 66. A lamellibranchiate mollusk, the common clam or quahog (*Venus mercenaria*), partly dissected: *g*, gills, mainly cut away; *m*, mantle; s^1 and s^2, upper and lower siphons; *aa* and *pa*, anterior and posterior adductor muscles; *ht*, heart; *h*, hinge; *u*, umbo.

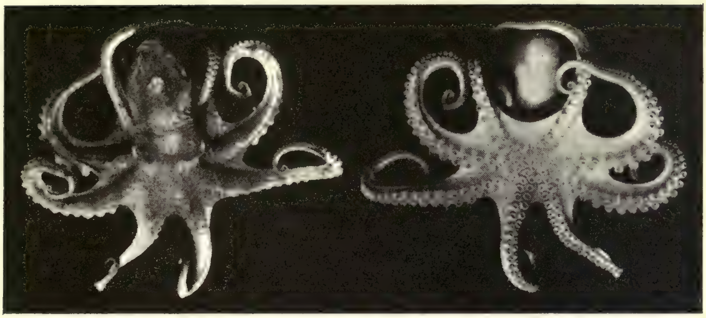
foot is adapted for burrowing and consequently without a flat surface or sole. The shell is hinged above, and the mantle adds material all along the margins, producing concentric lines of growth. Within the mantle, between it and the foot, are the leaflike gills. The mantle edges are usually united posteriorly to form more or less tubular organs called *siphons*. The upper of these, the anal siphon, is for the purpose of getting rid of waste water and food materials. The lower or branchial siphon is the one through which water enters, carrying oxygen in solution, which is absorbed through the surface of the gills. When the valves of the shell are examined, it will be seen that there is an apical point, representing the earliest stage of the shell; this is the *umbo*. Below the umbo is the *hinge*, which in some species is large and complicated. Within are seen the anterior and posterior scars of the *adductor muscles*, which close the shell. Passing from one to the other, but variously curved, is the *pallial line*, marking the attachment of the mantle. Many species of bivalves,

Pearls

particularly the large fresh-water mussels, have the shell lined within with a beautiful pearly substance, the *nacre*. In the region of the Ohio and Mississippi rivers the shells of these mussels are used as a source of pearl buttons, while occasionally the nacre forms around some object in a globular fashion, and is then a true pearl. It has been found that pearls result from the presence of parasites, which are inclosed and rendered harmless by the secretion of nacre.

Cephalopoda

6. The *Cephalopoda* or head-footed mollusks include the octopus, squid, nautilus, and the extinct ammonites. Although the shell is spiral, the animals are symmetrical. The foot forms a series of appendages surrounding the mouth; thus the octopus derives its name (eight-



A *B*

FIG. 67. An octopus. *A*, upper surface showing body and eyes, *B*, lower surface showing the adhesive disks.

footed) from the eight long tentacles, which bear adhesive disks. The eyes are often exceedingly large and well developed, superficially extremely like those of vertebrates, and possessing similar parts. Since the mollusks belong to quite a different stem from the vertebrates, the independent development of eyes so similar in form is a remarkable example of "convergent evolution." Most cephalopods (but not the *Nautilus*) have an ink sac, from which is expelled a black substance serving to confuse an enemy and facilitate successful flight. In function it corresponds with the "smoke screen" used by steamers as a protection against submarines. It is this black material which has been used as a paint under the name of "sepia."

The eyes

The ink sac

The shell may be absent, as in the *Octopus*. When present, it may be external, as in the *Nautilus*, or internal. In the latter case it may be quite rudimentary, a condition paralleling that of the slugs. The nautilus and ammonite shells are divided internally by *septa* into a series of compartments, only the last or outer of which is occupied by the animal. In former geological ages the Cephalopoda were more abundant and varied

Shell of the nautilus and ammonite

FIG. 68. Shell gallery, British Museum Natural History, London, showing large models of cephalopods suspended from the ceiling.

than at present, and were especially represented by the ammonites, sometimes as large as a cart wheel.

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CHAPTER THIRTY-FIVE

ARTHROPODA

Antiquity of Arthropoda

The phylum Arthropoda (from the Greek, meaning "with jointed feet") includes more species of animals than all the other phyla combined. It is of immense antiquity, with representatives in the Cambrian rocks, laid down not less than 30 millions of years ago. A terrestrial form, a scorpion, is known from the Silurian strata, and is more than 20 millions of years old. Unlike some of the ancient groups, the arthropods have continued to flourish up to the present time, producing in all ages vast numbers of genera and species, adapted to almost every conceivable condition of life.

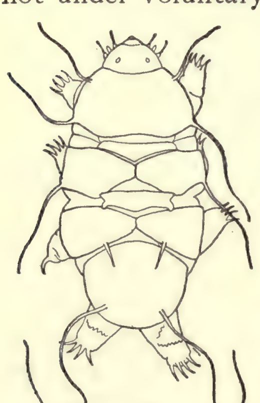
Evolution of Arthropoda

The earliest known arthropods were marine, and must have been derived from some primitive type of segmented worm. The characteristic feature is the external more or less hard covering (exoskeleton), the essential basis of which is the hornlike substance *chitin*, though there may be also a deposit of carbonate of lime, as in the larger crustacea (crabs and their relations). In the segmented worms paired appendages (*parapodia*) are frequently well developed. These are muscular projections from the body, and often bear remarkable chætæ or bristles, which may be jointed. The arthropod has such paired appendages still further developed, the majority being jointed and serving as legs. They commonly are bristly or hairy, and bear one or two claws at the extremity. With the development of a hard surface, segmentation is necessary to permit flexibility; so not only the body but also the appendages are jointed at intervals. Among the vast numbers of arthropods known, species will be found which do not agree with the general definition of the

phylum. They may be quite soft-bodied and legless, so that on inspection one would never suspect their relationships. In such cases the zoölogist is guided by the general structure, which serves to indicate relationships with more typical or ordinary forms. In many groups degenerate members are found living a sedentary or parasitic life, and losing the striking peculiarities which were developed by their ancestors.

The Tardigrada or water bears

A very singular and perhaps really primitive type of arthropod is the so-called water bear. Water bears or *Tardigrada* are microscopic animals found in ponds and ditches, along with Protozoa, rotifers, and small worms. They are transparent, more or less cylindrical, but fairly stout, with four pairs of short, stout legs which are not very different from the parapodia of worms. There is a simple alimentary canal, but there are no well-developed mouth parts or definite breathing organs or blood system. The muscular fibers of the body and appendages are unstriated, as in the case with muscles not under voluntary control. Each individual carries the organs of both sexes, and is therefore said to be hermaphroditic.



Drawing by W. P. Hay

FIG. 69. *Echiniscus*, one of the Tardigrada; greatly enlarged.

What are we to think of such a type? Is it really a primitive form allied to the worms, and surviving from a bygone age? Or is it a degenerate descendant of a more highly developed ancestor? In any event, it is today an isolated group, regarded as more or less related to the mites, but really without cousins in this world. The species seem to be

few, but they have been little studied in this country. Any one who will investigate them patiently is sure to make discoveries. Although the group is essentially a fresh-water one, there are very few marine representatives, while some are terrestrial, living in damp places. Regarding the arthropods broadly, we divide them into two great series: one adapted to aquatic life and usually breathing by means of gills; the other characteristically terrestrial. The first includes the Crustacea, the second the Arachnida, Prototracheata or Onychophora, Myriapoda, and insects. On investigation, we find land Crustacea and aquatic arachnids and insects; so the distinction of habitat is only broadly valid. We find, however, that such animals as the insects and spiders have developed special organs for breathing air, and certain of them, when living in the water, carry a bubble of air entangled in the hairs of the abdomen. We are reminded of the whale, a mammal which has become modified for aquatic existence, but is still obliged to breathe air. Yet many insect larvæ, such as those of the may-flies, breathe the oxygen dissolved in the water. These have developed gills, but apparently not very efficient structures, since in many cases the animals can live only in running water, where a new supply of oxygen is continually brought to them. Everywhere the tendency is for each group to develop members fitted for every available mode of life, aquatic and terrestrial, free and parasitic, motile and sedentary, limited in this by the ability to vary and by the competition of those which got there first. In the sea the Crustacea are dominant, and insects, so successful on the land, are practically absent. In the fresh water insects abound, but the Crustacea also are numerous. On the land insects may be said to rule, the combined terrestrial

Development of air-breathing structures

Habitats of insects and crustaceans

members of the other groups being relatively insignificant in numbers. Just as the insects seem with difficulty to invade the waters, so the Crustacea appear to find it hard to succeed on land. The isopod Crustacea, called wood lice and pill bugs, are widespread, but not very numerous in terrestrial species. Living in damp spots and under stones, they manage to breathe air, and in some cases have developed tracheal tubes corresponding in function to those of the insects. Yet on the whole they have no chance to compete with the insects, which are so perfectly adapted for aërial conditions.

Structure of insects and crustaceans

It is characteristic of the Crustacea that they have two pairs of antennæ, whereas the insects and myriapods have only one, and the arachnids are wholly without these structures. Here, again, exceptions occur; some Crustacea have only one pair of well-developed antennæ, and there are insects which have none. Insects never have more than six legs, except in some larvæ, such as the caterpillar. The other groups usually have more than six, in many cases a much larger number. Of all the groups, only the insects are winged. Before reviewing the arthropods in detail, it will be useful to give a summary of the principal groups.

CHAPTER THIRTY-SIX

PHYLUM ARTHROPODA

Class *Crustacea*

Subclass *Trilobita*

The trilobites, now entirely extinct, were formerly very abundant in the sea. They were highly developed as early as Cambrian time. The body was segmented, and bore very numerous jointed appendages. It is possible that these primitive crustacea gave rise to some centipedelike type which took to the land, developing tracheæ or air tubes for breathing. It has been suggested that in this manner the trilobites may have been remote ancestors of the insects; but Dr. G. C. Crampton, of the Massachusetts Agricultural College, has lately given good reasons for excluding them from the direct line of ancestry. At the time when the insects were becoming dominant the trilobites were disappearing. **The trilobites, an ancient group**

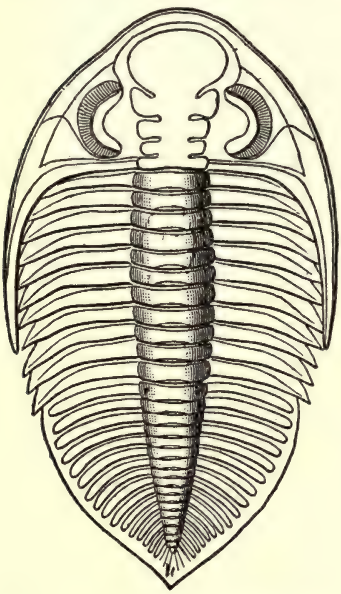


FIG. 70. A trilobite, *Dalmanites*, showing the dorsal surface.

Subclass *Eucrustacea* (or *Crustacea* proper)

The appendages are modified in various ways, for locomotion, for feeding, and as organs of sense. Conse- **Appendages**

quently the larger crustaceans, such as the crayfish, which are easy to examine, are commonly used to illus-

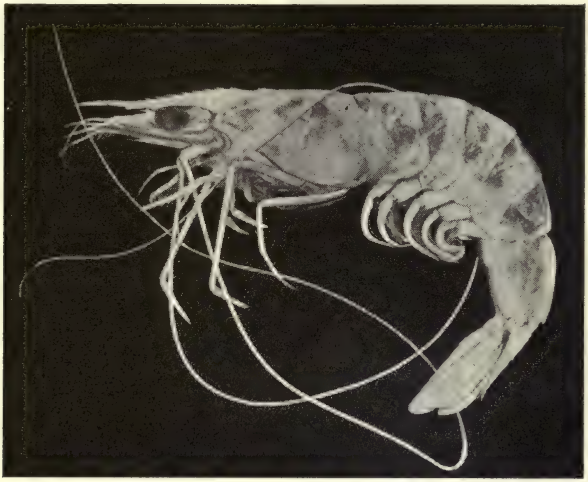
Photograph by W. P. Hay

FIG. 71. A "lady crab" (*Ovalipes ocellatus*), about half natural size. Found in the sea along the Atlantic coast.

trate an important evolutionary principle, the modification for various functions of a series of originally similar parts. It is not difficult to see that the two pairs of antennæ, the mouth appendages and the feet, are built upon the same general plan, but are greatly altered in detail to serve different purposes. The same principle is illustrated in the mammalian teeth, which are variously modified for grinding and cutting, or in the hands and feet of man. The typical crustacean appendage is said to be *biramose* (two-branched); that is to say, it has a basal part and two terminal parts, like a hand with two fingers. The outer of these terminal parts is called the *exopodite* (outer leg part) and the inner the *endopodite* (inner leg part). In this respect the Crustacea differ from the terrestrial group of arthropods, but the legs of terrestrial Crustacea (Isopoda), as well as of many aquatic forms, are without the ter-

Modification of appendages

minal division. No doubt the early Crustacea, with branched appendages, were essentially swimmers, and



Photograph by W. P. Hay

FIG. 72. A prawn (*Palæmonetes*), which occurs in great numbers along the south Atlantic coast and is extensively used as food.

Evolution of walking legs

the unbranched leg has evolved for walking, whether in the water or on the land. Adaptation for walking in the sea, and on the rocks and seaweed at low tide, made possible the eventual population of the land by arthropods. The *Entomostraca* are mostly small Crustacea, especially abundant in fresh water, and including some very ancient types. The "higher" and mostly larger Crustacea are called *Malacostraca*. Some, such as the crab and crayfish, possess a *carapace* or shield covering the thorax; others, including the terrestrial wood lice, are without this structure.

Class *Arachnoidea*

A great series of arthropods in which the antennæ are wholly absent and the head and thorax are usually fused into a *cephalothorax*.

Subclass *Xiphosura*

Photograph by W. P. Hay

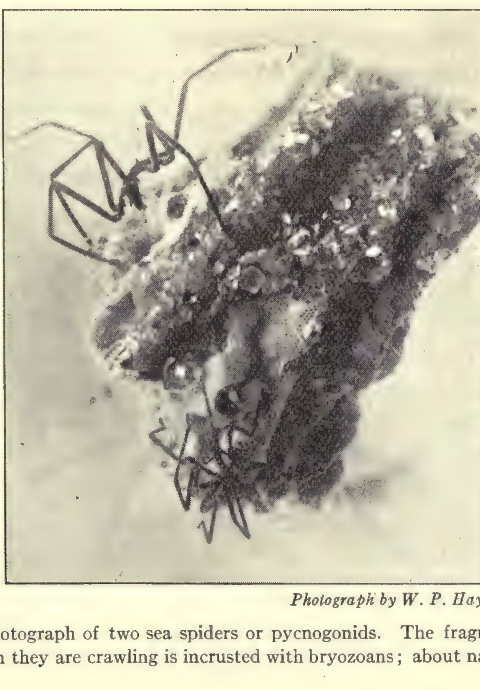
FIG. 73. A horseshoe crab (*Limulus*) showing the ventral surface; about ¼ natural diameter.

Aquatic animals, known as horseshoe crabs, on account of the outline of the cephalothorax. They differ from the true arachnids in possessing gills. The name Xiphosura (sword tail) refers to the swordlike (or spinelike) tail. The horseshoe crabs, or king crabs, which of course are not crabs at all, grow to a large size, and may be found in abundance in the sea along our Atlantic coast. Large specimens are about a foot and a half long, and the color is dark brown. Although the individuals are many, all belong to a single species, *Limulus* (or *Xiphosura*) *polyphemus*. Several others occur in Asiatic seas, but the group is a very small one in the existing fauna, evidently an ancient type represented by a few survivors. At Mazon Creek, Illinois, nodules of the carboniferous period are found containing fossil animals and plants, and among them a primitive king crab called *Euproops danæ*. This animal, which lived more than ten million years ago, inhabited fresh water; so it is not unlikely that the Xiphosura had their origin in inland waters.

Ancient Xiphosura

Subclass *Arachnida*

Mainly terrestrial animals, the most familiar being the spiders and scorpions. The group also includes the mites, of which many are aquatic, some living in the sea. There is also a remarkable and aberrant group, with small body and very long legs, known as sea spiders (*Pycnogonida*), and found exclusively in the sea. These differ so much from the typical arachnids that they should probably form a separate subclass. The most ancient arachnids appear to be those with a distinctly segmented abdomen, such as the scorpions and harvest men. Even the spiders, which today are characterized by the unsegmented abdomen, formerly had **Characters of arachnids**



Photograph by W. P. Hay

Fig. 74. Photograph of two sea spiders or pycnogonids. The fragment of coral over which they are crawling is incrusted with bryozoans; about natural size.

FIG. 75. A scorpion (natural size).

distinct abdominal segments, as the older fossils distinctly show. A very few Asiatic species still have this character fairly well developed, at least on the upper surface.

The mites, though mostly very small, include the ticks, some of which are as large as peas, or even larger. Although the arachnids have nearly always four pairs of legs, whereby they differ at once from the insects, which have only three, the gall mites have the legs reduced to two pairs. The simple eyes (usually eight) of the spiders contrast with the large compound eyes of

FIG. 76. A wolf spider.

the insects; but the insects also have simple eyes (*ocelli*).

Class *Prototracheata*

The arthropods, with their jointed legs and usually hard chitinous covering, seem isolated in the animal kingdom. The various soft-bodied and legless members of the group, such as the female scale insect, are obviously not primitive, but highly specialized. Looking for some real relative outside of the arthropod phylum, we can turn only to the higher worms. These are adapted for life in the water or in moist earth, whereas the majority of the arthropods live on the surface of the earth or on plants. The Crustacea do indeed inhabit the waters in great numbers, but they show little resemblance to worms. There is, however, one group of animals which, although terrestrial, is soft-bodied, without chitinous body rings, and doubtless primitively so. Superficially, at least, it seems to combine the features of a worm with those of a centipede. The *Peripatus*, first discovered in the Island of St. Vincent, West Indies, was taken by its discoverer for some strange kind of slug. This was in 1826, and since that time many related species have been found, widely scattered over the earth, so that today over 70 different forms can be enumerated. It is found that these animals breathe by means of *tracheæ*, — that is to say, minute tubes connected with small openings on the surface of the body. Hence the group has been called Prototracheata, or first (in the sense of primitive) trachea-breathing animals.[1] They resemble the terrestrial arthropods in this feature, but the tracheal openings are scattered over the surface of the body, instead

The tracheal system

[1] It is also called Protracheata and (more generally) Onychophora.

of being in pairs, one on each side of each segment. Since the form of the tracheæ and other structural features in the *Peripatus* are very unlike those of the typical tracheate arthropods, such as the insects, it is evident that we can regard the Prototracheata only as a relatively primitive type, not in any sense as truly ancestral. It is a branch from an early stock which came off very long ago, and has been modified in its own way, which is not the way of the insects or spiders. At the present time the species are widely scattered and generally rare, as is usually the case with an ancient and waning stock. When alive, the Peripatus is a very handsome animal, with a soft, velvety skin, which in some species is very beautifully colored with subdued shades of reddish or greenish. The numerous pairs of soft legs remind one of the abdominal legs of a caterpillar, while the soft, flexible antennæ are not unlike the tentacles of a snail or slug. The form figured was found in South Africa. No kind of Peripatus is

Distribution of Peripatus

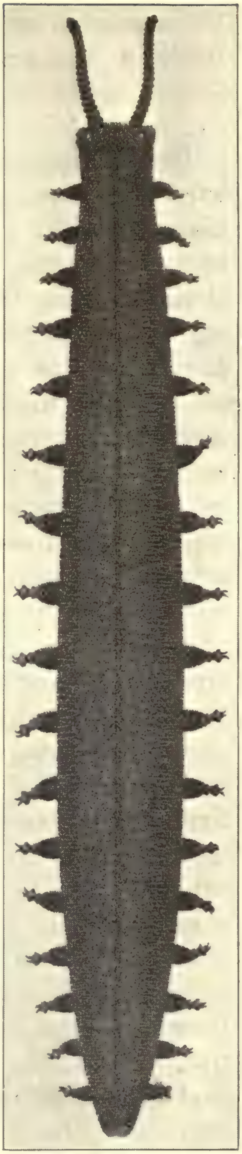


FIG. 77. Peripatus (Peripatopsis) capensis, × 3; viewed from the dorsal surface. The largest specimen recorded was 65 mm. long.

After drawing by Miss Balfour

known from the United States, but there are species in Mexico, South and Central America, and the West Indies, and no fewer than five inhabit the Isthmus of Panama.

Class *Diplopoda*

The millipedes, usually with long cylindrical bodies, and most of the segments bearing two pairs of legs. They move slowly, and usually curl up when alarmed. The surface of the body is typically smooth or tuberculated, often shiny. A very ancient fossil form (*Palæocampa*, from Mazon Creek, Illinois) was profusely hairy, and the curious little Polyxenus, still living in various parts of the world, is hairy. In Mexico and other southern countries very large millipedes, as long as a finger, may be found. The millipedes and centipedes have commonly been classed together as a great group *Myriapoda* (many or myriad legs), but they are really very distinct groups, though agreeing in the single pair of antennæ and the numerous segments and legs. **Millipedes**

FIG. 78. Two millipedes.

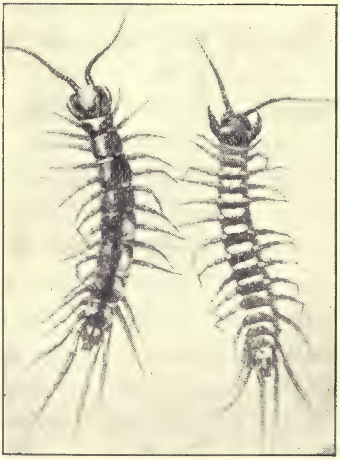


FIG. 79. Dorsal and ventral views of a common centipede.

Class *Chilopoda*

Centipedes

The centipedes are so called because they are supposed to have a hundred legs, though the number differs, in different forms, from thirty to over three hundred. They differ from the diplopods in having only one pair of legs to a segment, and by the greater number of joints to the antennæ. In the diplopods the antennæ do not have more than seven joints, in the chilopods they have at least twelve. Some centipedes (*Scolopendra*), common in the Southern and Western states, are very large; others (*Geophilus*) are small and extremely slender. The *poison claws* represent the first pair of legs, greatly modified. They are connected with glands, and the secretion flows through a passage opening near the tip of the claw.

In addition to the important classes Chilopoda and Diplopoda, there are two represented by minute and rarely observed species. Both have only one pair of legs to a segment, though in other respects they differ greatly from the chilopods.

The Symphyla

The *Symphyla* (*Scutigerella* and *Scolopendrella*) differ from the chilopods in lacking maxillipeds (jaw feet), or modified legs serving as mouth parts. They have twelve pairs of legs, and the antennæ are quite long, sometimes with as many as fifty joints.

The Pauropoda

The *Pauropoda* (*Pauropus* and *Eurypauropus*) are more like diplopods, with short and curiously modified antennæ, which are branched at the end. They wholly lack special respiratory organs, whereas the diplopods possess tracheæ (air tubes), with openings (spiracles) at the bases of the legs. Symphyla and Pauropoda may be found under stones or stumps in damp places, and are probably more widely spread than the published records show, as owing to their minute size they have been overlooked.

Class *Insecta*

The insects, the most abundant of all animals. The head is distinct, and there are typically three pairs of legs, all attached to the thorax. In the majority of species there are two pairs of wings; but these may be reduced to two, as in the flies (Diptera), or may be altogether absent. When the wings are absent, they may be primitively so (e.g., Collembola), or the animals (such as the louse and bedbug) may be evidently derived from winged ancestors. There is usually a distinct *metamorphosis*, or change in form during growth. This may be extreme (complete), as in the butterflies, which hatch from eggs as caterpillars, pass through the dormant chrysalis stage, to emerge as an adult (imago) totally unlike either caterpillar or chrysalis. The wings are never developed until the adult stage is reached, and after reaching the adult or imago stage the animal grows no more. If it ever seems to do so, it is only because the body becomes distended with eggs.

Characters of insects

The classification of insects is in an unsettled condition, owing largely to differences of opinion as to the number of orders and other divisions to be recognized. Some authors recognized even five different classes, four of which are based on the primitively wingless forms often treated as an order Aptera. Our present treatment represents a less extreme point of view, but like all other classifications is subject to revision. We begin with the groups which seem to be most primitive.

Order *Protura*

Minute wingless terrestrial insects, slender in form and without antennæ. Some are without a tracheal system. There are six legs, the front pair held forward

and used as organs of touch, in the absence of the antennæ. The first three abdominal segments have short appendages. These singular little animals were first made known by the Italian entomologist, Silvestri, in 1907, but have since been found in many countries. They combine primitive with specialized characters.

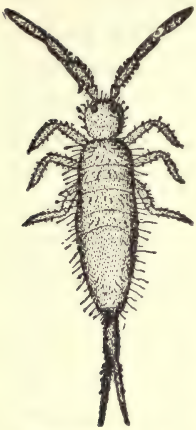


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FIG. 80. A springtail (*Entomobrya*); greatly magnified.

Order *Collembola*

Springtails

Small, wingless terrestrial insects, without metamorphosis. The antennæ are well developed, but have few joints. A forked appendage (furcula) beneath the abdomen enables the insect to leap; in one group this is absent. The body is sometimes clothed with scales. These small creatures, known as "springtails," may be found under rocks. One kind occurs on snow in the winter.

Order *Thysanura*

Thysanura or "silver fish"

Wingless terrestrial insects with slender antennæ and six legs. They do not leap, and are generally much larger than the Collembola, though of no great size. A common form, found in houses, is somewhat carrot-shaped, with silvery, glistening scales, and is popularly known as the "silver fish." It is about one third of an inch long, and has three long tails.

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FIG. 81. A "silver fish" (*Lepisma*).

Campodea represents a very different group of Thysanura, or perhaps distinct order; a soft, fragile white animal, with two long tails instead of three. It occurs in damp places.

Order *Orthoptera*

Terrestrial insects with incomplete metamorphosis, the pupa stage being active. The mouth parts are well developed, for biting. The anterior wings, called *tegmina* (singular, *tegmen*), fold over the abdomen; but in many species the wings are absent. The grasshopper, cricket, and cockroach are familiar Orthoptera. It will be noted that some, presumably the most primitive, have no power to jump, while others possess large hind legs and leap vigorously. The former type is illustrated by the cockroach, mantis, and earwig, the latter by the grasshopper, cricket, and locust. For additional particulars see Chapter 42.

Grasshoppers, crickets, and cockroaches

Order *Archiptera*

Stone flies and May flies

This includes the stone flies (Perloidea or Plecoptera) and the May flies (Ephemeroidea or Plectoptera), often regarded as representing two distinct orders. They are winged insects, with incomplete metamorphosis, the immature

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Fig. 82. A stone fly (*Pteronarcys*).

stages passed in fresh water. The stone flies have two tails, and the wings fold over the body as in the cockroaches. The similar segments of the thorax in the young closely resemble those of very ancient fossil insects. The antennæ are long and slender. The May flies, noted for the brief period of their adult life, usually have three tails, while the antennæ are short and inconspicuous.

Order *Odonata*

Dragon flies The dragon flies; usually large insects, passing their early stages in the water, the ugly young being absurdly called *nymphs*. They are carnivorous in all stages. The larva is active, and has no resting stage before transforming into an adult. The adult insect has biting mouth parts, very small, threadlike antennæ, and very well developed wings. The species differ greatly in size, one having wings only about 9 mm. long, while in another the hind wing of the female reaches 94 mm.

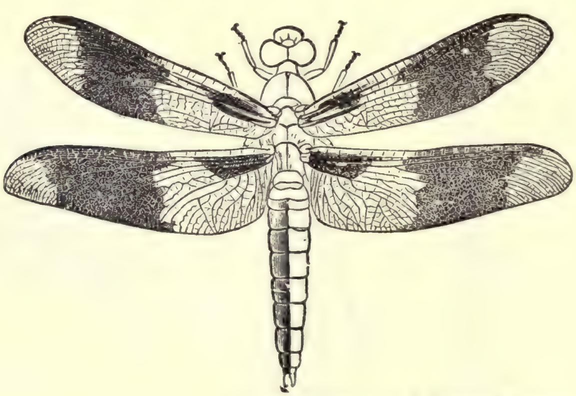

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Fig. 83. A dragon fly (*Plathemis*).

Order *Neuroptera*

Lace-wing flies and ant lions

A quite miscellaneous assemblage of insects, having the veining of the wings more or less netlike, including the lace-wing fly (*Chrysopa*) and the ant lion. In most cases the larvæ are terrestrial, but the Dobson flies and their relatives, often placed in a distinct order, have aquatic larvæ.

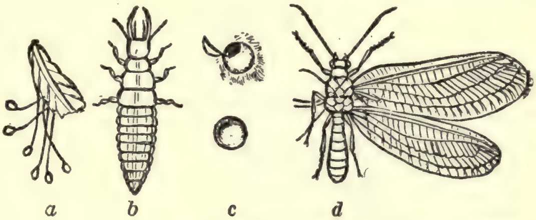

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FIG. 84. A lace-wing fly (*Chrysopa*): *a*, eggs; *b*, larva; *c*, cocoons; *d*, adult fly with left wings removed.

Order *Isoptera*

Termites

The so-called white ants, which are not ants, while some of them are black. They are strictly terrestrial,

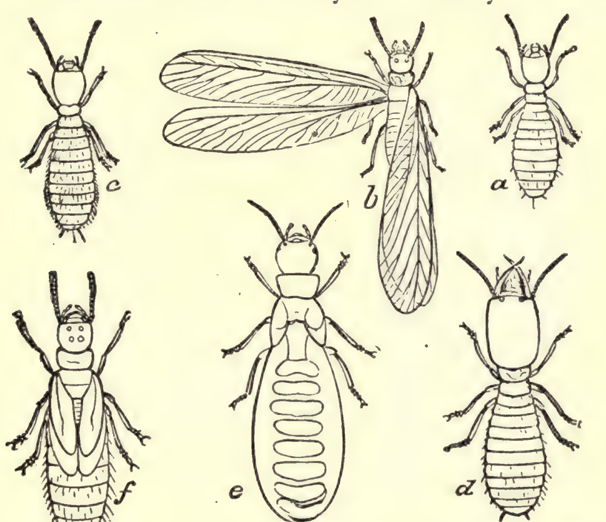

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FIG. 85. A "white ant," *Termes flavipes*: *a*, worker; *b*, male; *c, e, f*, stages of female; *d*, soldier.

with imperfect metamorphosis, and are remarkable for their social life in large colonies. The anterior and posterior wings are similar to one another.

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FIG. 86. A "tree louse," *Psocus venosus* (*Corrodentia*).

Order *Corrodentia*

The book lice (which are not lice) and their relatives; very small insects with long, slender antennæ and incomplete metamorphosis. In one group the wings are well developed, in another group they are absent.

Order *Mallophaga*

Biting lice Biting lice, abundant on birds, though some genera infest mammals. They are wingless.

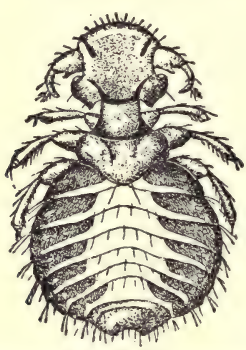

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FIG. 87. A bird louse, *Goniodes falcicornis* (*Mallophaga*).

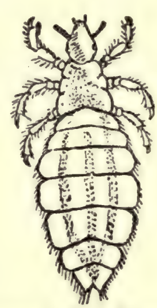

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FIG. 88. A head louse, *Pediculus capitis* (*Siphunculata*).

Order *Siphunculata*

True lice The true lice, including those infesting man. The mouth is beaklike, adapted for sucking.

Order *Thysanoptera*

Small insects known as thrips, common on flowers. **Thrips** They feed on the sap of plants, and are often injurious. The metamorphosis is quite incomplete. Wings are usually present in the adults, but many species are wingless.

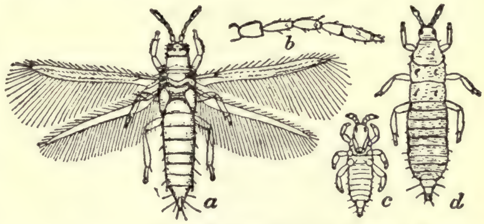

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FIG. 89. Tobacco thrips: *a*, adult; *b*, antenna of same; *c*, young larva; *d*, full-grown larva.

Order *Trichoptera*

The caddis flies, formerly placed with the Neuroptera, **Caddis flies** but really more nearly allied to the Lepidoptera. The larvæ are aquatic, and usually construct cylindrical cases. In one genus the larva case resembles a snail, and was once described as such by an eminent naturalist. Some of the adults are so similar to moths as to lead to confusion, but the hind wings are folded lengthwise when at rest, which is not true of the Lepidoptera.

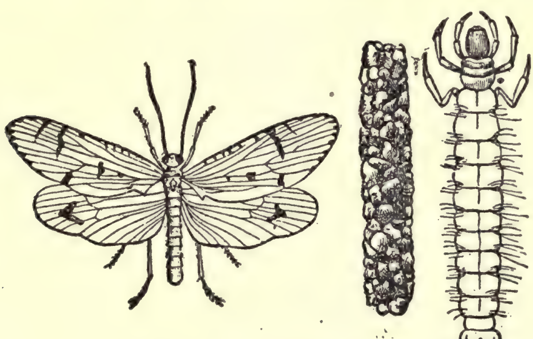

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FIG. 90. A caddis fly, larva, and its case.

Order *Lepidoptera*

The butterflies and moths, or scale-winged insects; with complete metamorphosis; the larvæ terrestrial, with few exceptions. See Chapter 38.

Order *Mecaptera* (or *Panorpatæ*)

Scorpion flies

Scorpion flies and their relatives, often regarded as a suborder of Neuroptera. The head is prolonged into a beak. The males of *Panorpa*, the true scorpion flies, have the end of the abdomen enlarged and curved upward, in the manner of scorpions. The wings when present are more or less narrow, the anterior pair similar to the hind ones. Frequently the wings are prettily marked. The metamorphosis is complete, and the larvæ resemble caterpillars. All the species are carnivorous, feeding on other insects.

From Bulletin 67, U. S. National Museum (after Packard)

FIG. 91. A scorpion fly (*Panorpa*).

Order *Hymenoptera*

Bees, wasps, etc.

The bees, wasps, ants, sawflies, and their relatives. See Chapters 39 and 40. The most primitive Hymenoptera are the sawflies, in which the abdomen is broadly attached to the thorax, and the larvæ have legs, those which feed exposed on foliage closely resembling caterpillars. Another great group consists of the ichneumon flies, chalcid flies, and others, nearly all parasitic in their immature stages on other insects, and of great importance as destroyers of insects injurious to crops.

The wasps are very diverse, belonging to two entirely different series, one of which (the digger wasps) is closely related to the bees. The ants are not closely related to

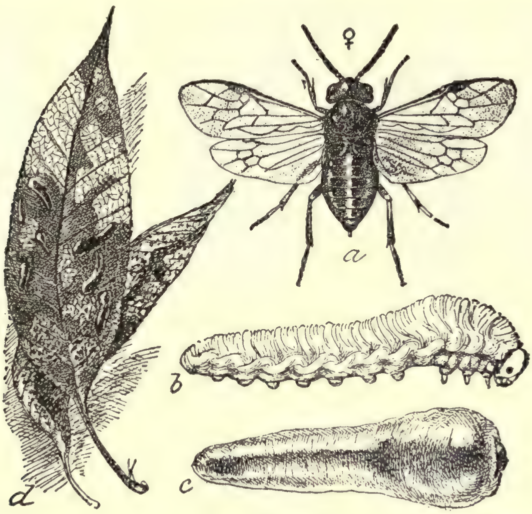

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FIG. 92. A sawfly, the so-called pear-slug (*Caliroa cerasi*): *a*, adult; *b, c*, larva (enlarged); *d*, larvæ on leaf.

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FIG. 93. A chalcis fly (*Spilochalcis mariæ*); enlarged.

the bees, and have acquired social habits quite independently. All Hymenoptera have the metamorphosis complete.

Order *Coleoptera*

Beetles

The beetles, usually easily recognized by the hardened anterior wings, called *elytra* (singular *elytron*), which in

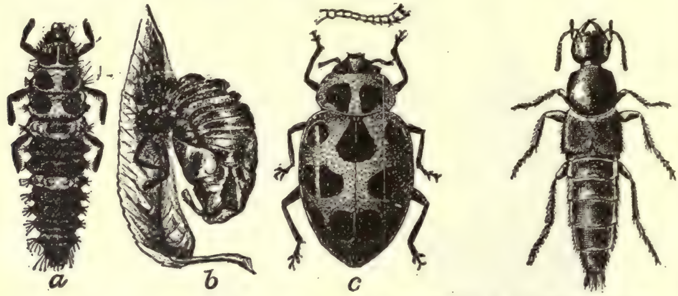

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FIG. 94. A "ladybird" beetle (*Megilla*) : *a*, larva ; *b*, pupa ; *c*, adult beetle (enlarged). The figure at the right of the illustration is a rove beetle (*Philonthus*), enlarged.

the majority of species cover the abdomen and conceal the membranous posterior wings. The posterior wings are folded when at rest. The mouth is mandibulate; that is, adapted for biting, as in the Hymenoptera and Orthoptera. The metamorphosis is complete. The antennæ usually have ten or eleven joints.

A small group of minute insects, parasitic on bees and other insects, has been separated as an order *Strepsiptera*, but it may be considered a suborder of Coleoptera.

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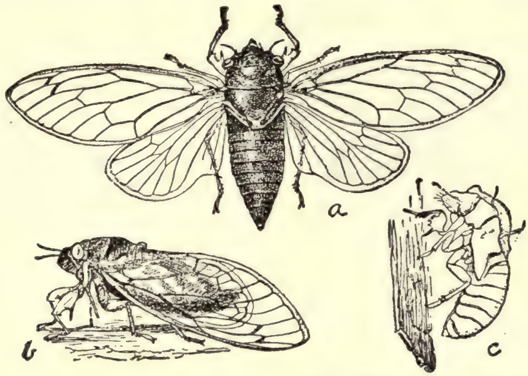
FIG. 95. A bug, *Leptoglossus oppositus*, one of the Hemiptera.

Order *Rhynchota* (or *Hemiptera*)

The plant bugs, cicadas, plant lice, scale insects, and

other diverse forms, characterized by the incomplete metamorphosis and the sucking instead of biting mouth

The Rhynchota



From Bulletin 67, U. S. National Museum

FIG. 96. The "seventeen-year locust" (*Tibicina septendecim*): *a, b,* adult insects; *c,* shell of nymph, after emergence of adult.

parts. In male scale insects the metamorphosis is more nearly complete, there being a resting pupa stage.

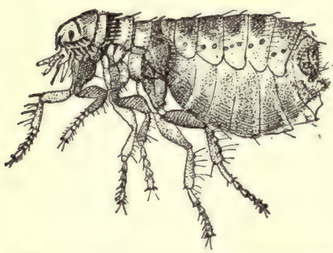
Divisions of Rhynchota

The Rhynchota consist of two great divisions, by some regarded as separate orders. In the *Homoptera* the anterior wings are of nearly the same consistency throughout, whereas in the *Heteroptera* (or *Hemiptera* proper) the front wings or hemelytra are membranous apically, with the basal part more or less hard and opaque, in the manner of the elytra of beetles. The division between the two parts is abrupt, and the dividing line is more or less oblique. The *Homoptera* include some very peculiar groups, such as the scale insects (Chapter 41) and aphids or plant lice, but the more typical form of the suborder is that of the so-called seventeen-year locust, a large species of cicada. The *Heteroptera* include many plant bugs, and others which are predatory, feeding on different insects. Some, such as the bedbug, suck the blood of vertebrates.

Order *Siphonaptera*

Fleas

The fleas; small, wingless, jumping insects with compressed bodies, somewhat related to the flies. The metamorphosis is complete and the mouth is formed for sucking. The antennæ are short and relatively inconspicuous. The bacillus of bubonic plague is carried by fleas, which accordingly become of great economic importance in some countries.



From Bulletin 67, U. S. National Museum

FIG. 97. A flea.

Order *Diptera*

Flies

The true flies, having only two wings. The mouth parts are adapted for lapping or sucking, and the metamorphosis is complete. In the presumably more primitive Diptera (suborder *Nematocera*) the antennæ are more or less long, with many joints. This series includes the mosquitoes, gall gnats, crane flies, and others less familiar. The higher Diptera have the antennæ short, or at

From Bulletin 67, U. S. National Museum

FIG. 98. A robber fly (*Eicherax*) with its larva and pupa.

From Bulletin 67, U. S. National Museum

FIG. 99. A green-bottle fly (*Lucilia*), showing the thoracic bristles.

any rate with few joints, usually three. At the end of the series we place such forms as the house fly and tsetse fly, in which the pupa is entirely inactive. The more highly specialized flies are remarkable for the arrangement of the bristles on the thorax. In addition to the general covering of fine hair (pubescence), there is a series of regularly placed bristles, the position and number of which characterize different genera and species. The bristles on the head also are very important. Various Diptera are connected with the propagation of the germs of disease, as we have seen in Chapter 26.

Chaetotaxy, or the study of bristles

From Bulletin 67, U. S. National Museum

FIG. 100. A crane fly (*Tipula*).

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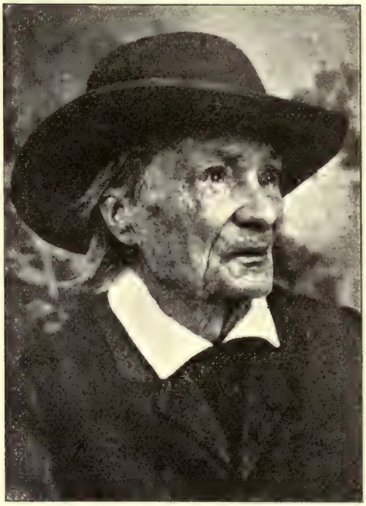
CHAPTER THIRTY-SEVEN

HENRI FABRE

The spirit of Fabre

1. "Do you know the Halicti? Perhaps not. There is no great harm done; it is quite possible to enjoy the few pleasures of life without knowing the Halicti. Nevertheless, when questioned with persistence, those humble creatures with no history can tell us some very singular things; and their acquaintance is not to be disdained if we desire to enlarge our ideas a little upon the bewildering rabble of this world.



By courtesy of Dodd, Mead & Co.

FIG. 101. J. Henri Fabre.

Since we have nothing better to do, let us look into these Halicti. They are worth the trouble." With these persuasive words does Fabre, combining the spirit of the poet with that of the naturalist, introduce us to those wild bees which abound in both hemispheres, unnoticed by the common man. To him all life is interesting; and especially insect life, on account of the remarkable character and diversity of its manifestations. Every garden, every hedgerow, is a veritable wonderland.

Fabre's early years

2. J. Henri Fabre, born in 1823, spent his long life in the warm, fertile region of the south of France, where the Rhone wends its way toward the sea. There was one exception to this statement; a brief period in Corsica, as teacher of physics in the college at Ajaccio, gave

him access to a new fauna and flora and greatly stimulated his scientific interests. Sometimes he regretted his inability to visit remote regions. "To travel over the world, by land and sea, from pole to pole; to cross-question life, under every clime, in the infinite variety of its manifestations, — that surely would be glorious luck for him that has eyes to see with; and it formed the radiant dream of my young years, at the time when *Robinson Crusoe* was my delight. These rosy illusions, rich in voyages, were soon succeeded by dull, stay-at-home reality. The jungles of India, the virgin forests of Brazil, the towering crests of the Andes, beloved by the condor, were reduced, as a field for exploration, to a patch of pebble-stones within four walls.

"Heaven forfend that I should complain! The gathering of ideas does not necessarily imply distant expeditions. Jean-Jacques Rousseau herbalized with the bunch of chickweed whereon he fed his canary; Bernardin de Saint-Pierre discovered a world on a strawberry plant that grew by accident in a corner of his window; Xavier de Maistro, using an armchair by way of post chaise, made one of the most famous journeys around his room.

Home surroundings

"This manner of seeing country is within my means, always excepting the post chaise, which is too difficult to drive through the brambles. I go the circuit of my enclosure over and over again, a hundred times, by short stages; I stop here and I stop there; patiently I put questions; and at long intervals I receive some scrap of a reply.

"The smallest insect village has become familiar to me. I know each fruit branch where the Praying Mantis perches; each bush where the pale Italian Cricket strums amid the calmness of the summer

nights; each wad-clad blade of grass scraped by the Anthidium (bee)." (See Chapter 39, page 296.)

Thus the necessity for remaining at home became an advantage. It was this intensive and loving study of his immediate environment which made it possible for Fabre to write his great work, or series of works, the *Souvenirs entomologiques*.

Fabre as a teacher

3. At the age of nineteen Fabre became a teacher of elementary subjects in the school at Carpentras. The salary was small, and the school a dismal place. Fabre, with his poetic and sensitive nature, was torn by opposite emotions. He taught with enthusiasm, always wishing to convey some of his own rich feeling, and of course met with a considerable measure of success. At the same time he was distressed by the prevalent conditions, the dirt and barbarism, the impossibility of attaining more than a fraction of what he aimed at. Thus he was glad to leave the primary work when a chance came to teach physics in the island of Corsica. It was this stay in Corsica which finally confirmed him in his devotion to natural history. Not only the greatly increased opportunities for observation, but a fortunate meeting with the naturalist Moquin-Tandon, gave this direction to his thoughts. Moquin-Tandon, professor at Toulouse, was a remarkable and versatile man who has left a strong impression on French science. He knew how to make zoölogy and botany interesting, and to use graceful language in describing the most abstruse details. It was a revelation to Fabre when this enthusiast showed him, in a plate of water, the anatomy of a snail.

Fabre's studies of insects

4. After a time Fabre returned to the mainland of France, to teach in the lycée of Avignon. Now began a period of twenty years, devoted to pedagogy and

entomology. It happened that a book by Leon Dufour, devoted to the natural history of insects, fell into his hands. The descriptions of insect life at once caused him to begin observations on his own account. There was an account of the wasp *Cerceris*, and its manner of storing its prey. Fabre soon discovered how much there was to learn, how extraordinarily inadequate and fragmentary were the researches of those who stood high in the world of science. Few had combined the genius and the patience to see things through, to follow in every detail the life of these small animals. Thus a new field opened up before him, and he cultivated it assiduously until from the infirmities of old age he could work no more. In all this he was very happy, but otherwise he was in the midst of difficulties. The small salary of about $500 a year did not suffice for the support of his growing family. He was obliged to do all sorts of miscellaneous tutoring, in order to increase his means. At length, utilizing his literary skill, he began to write textbooks of elementary science, and these in due time yielded a fair income. Thus it eventually became possible, when harassed by those who could not appreciate scientific teaching, for him to retire from the duties of the schoolroom and devote himself to research and writing. He lived in Orange, but later moved to Serignan, a peaceful and obscure village, where he could work undisturbed.

Fabre's writings as literature

5. In this modest retirement, far from the main currents of the world's affairs, Fabre won fame without seeking it. For many years his writings were well known to entomologists, but it was not until near the end of his life that the general public became aware of his existence. The masters of literature had come to realize that here was something more than a student of

technicalities, — a man who, while discussing insects, made noble contributions to the literature of France. Fabre's poetical and romantic instincts, which repelled some of the rigidly scientific, naturally appealed to literary men. The modern student of comparative psychology does not employ the language of the *Souvenirs entomologiques*, with its strong suffusion of human emotions. The question has naturally arisen, can we accept Fabre as a contributor to technical science? We can and must, for his observations are the best in his special field, but we may make allowances for the language. The controversy is an old one, with many aspects. To make nature live and move in literature is to see it with human eyes, — the only eyes we have; but we cannot do this and preserve an attitude of cold scientific detachment. In the hope of escaping from the human bias, we describe phenomena in scientific phrases, which possibly often do no more than decently cover the nakedness of our ignorance.

The festival at Serignan

6. Thus it came about that on the third of April, 1910, there was held a festival in the sleepy village of Serignan. Eminent men, scientific and literary, assembled to do homage to Fabre. A banquet was given in the large hall of a café, and Edmond Perrier, representing the Institute of France, described in a speech the life and works of the entomologist. "Moved to tears by his memories and by the simple and pious homage at last rendered to his genius, Fabre wept, and many, seeing him weep, wept with him." The *Souvenirs entomologiques* began to be translated into English, and were widely read on both sides of the Atlantic. They are now to be found in every large library, under various titles given by the translators and publishers.

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In using the translations from Fabre, it is necessary to remember that some errors have crept in, owing to the lack of entomological knowledge on the part of the translators.

CHAPTER THIRTY-EIGHT

LEPIDOPTERA

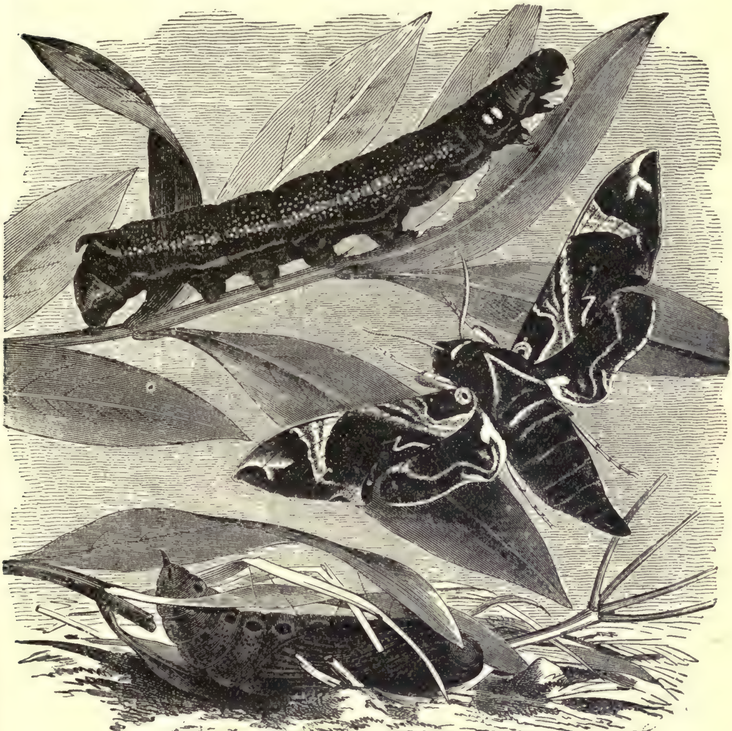
Characters of Lepidoptera

1. THE Lepidoptera or scale-winged insects (Greek *lepis*, a scale, and *pteron*, a wing) include the butterflies and moths. It is a curious thing that in English we have no single word to include both, in spite of the fact that few people can distinguish accurately between them. The old Latin *papilio*, though translated butterfly, was any lepidopterous insect; the same is true of the German word *schmetterling*. The scales which cover the wings of most Lepidoptera are flattened hairs, and on the same insect various transitional states may be found, from the scarcely or not modified hair to the broad, shinglelike scale. The possession of such scales is not in itself proof that an insect is lepidopterous; they may be found, for example, on mosquitoes. Even the relatively primitive Thysanura (page 268) have scales. The Lepidoptera, however, possess two pairs of wings, a sucking mouth, and have a complete metamorphosis.

The larva or caterpillar

Beginning life in the egg, they hatch as caterpillars, commonly but erroneously called "worms." The caterpillar is a remarkable creature, since it contradicts in so many features the characters of the adult. It is usually long and cylindrical, with a rounded head and eight pairs of legs. The anterior three pairs, attached to the thoracic segments, are the so-called true legs, representing the six legs of all adult insects. The remaining ten legs, attached to the abdomen, are soft and fleshy, and are sometimes called false legs, though they are veritable legs and function as such. They disappear entirely in the adult insect. The caterpillar also appears to have no antennæ, though there

are in reality very minute ones; and the eyes, instead of being compound, are simple and extremely small,



From "Animate Creation"

FIG. 102. The oleander hawk moth, with its caterpillar and pupa. This is a European species.

arranged in a little group on each side of the head. The mouth is provided with large mandibles, and hence the animal, in this stage, agrees with the primitive mandibulate group. The caterpillar feeds on plant tissue (a very few species devour other insects), and growing rapidly, changes its skin at intervals. That is to say, the skin splits open, and the caterpillar walks

out of it, clad in a new skin which had formed underneath. Caterpillars and reptiles are not the only animals which change their skins; we do likewise, only we do it gradually. Every time we wash our hands, dead skin cells fall away imperceptibly and new ones, formed underneath, take their place. The caterpillar is the *larva* stage, the word "larva" applying to this stage in any insect, "caterpillar" specifically to the larva of one of the Lepidoptera.

The pupa The caterpillar, becoming full fed, changes into a *pupa*, which may be exposed or in a cocoon, or may be buried in the ground, according to the species. The word "chrysalis" was applied to the pupa of certain butterflies, which shine with a golden luster. From the pupa emerges the moth or butterfly. The ancients, observing how many larvæ entered the ground and remained apparently dead all winter, emerging as beautiful moths next year, compared the adult or *imago* with the human soul. The buried pupa of course suggested the dead body, from which a perfect being should emerge on the day of resurrection.

Butterflies 2. The Lepidoptera are divided into several very distinct groups, of which the butterflies constitute one. In the butterflies (*Rhopalocera*) the antennæ are knobbed, whereas in the moths they come to a point. In some tropical groups this distinction is not perfectly clear, so that disputes have arisen as to whether certain species were butterflies or not. Commonly the butterflies are also distinguished by the fact that they fly by day, and when at rest hold the wings erect, one against the other. Neither of these distinctions is reliable, however, since many moths are day fliers, and the manner of holding the wings varies in both groups. The butterfly pupa is not inclosed in a cocoon, as are those of many

moths, nor is it buried in the ground. The various groups of moths are distinguished by the structure of the wings and mouth, as well as by the character of the larva. Thus the geometrids, or earth measurers, have caterpillars which possess fewer abdominal legs, and walk by bending the body in the shape of a letter U. Several families are included under the general term *Microlepidoptera*, and are noted for the small size of nearly all the species. At the other extreme are the often gigantic Saturniidæ, which include the large Asiatic silk moths, and the familiar American luna, cecropia, and polyphemus moths.

From "Animate Creation"

FIG. 103. Milkweed butterfly (*Danaus archippus*).

The lowest Lepidoptera show many features in common with the Trichoptera or caddis flies (page 273), from primitive members of which the whole order may be supposed to have arisen.

Protective coloration of moths

3. Lepidoptera are especially noted for the various characters which they possess, apparently enabling them to elude their enemies. Many species show *protective coloration;* thus, for example, the red-underwing moth, *Catocala*, when it settles on the bark of a tree, so perfectly resembles the surface on which it

Photograph by J. H. Watson

FIG. 104. *Grællsia isabellæ* on pine. This moth, which is found only in a limited area in Spain, and is named after Queen Isabella, is of a delicate pea-green color, the veins broadly covered with dark red scales. On the pine tree (*Pinus maritima*), on which it feeds, its colors produce an effect similar to that of the pine needles.

Warning coloration

rests that it is extremely hard to detect it. Some moths and caterpillars, however, are very conspicuous. Many years ago the naturalist Bates wrote to Darwin, calling his attention to an extremely gaudy tropical caterpillar of large size, ornamented with red, yellow, and black. How can such colors be of any advantage, it was asked? Must they not betray the larvæ to every passing bird? Darwin, puzzled, wrote to Wallace, who suggested that perhaps the caterpillars were distasteful to birds, and if so, the more easily they could be recognized the better chance they would have of avoiding the fatal experimental peck. This has since been shown to be really the case, and such examples are classed under the head of *warning coloration.* Still more remarkable are the resemblances between dif-

ferent Lepidoptera, classed under the head of *mimicry*. **Mimicry** This term is rather unfortunate, because it suggests intentional imitation, which is absurd, since the insects have no control over their appearance. H. W. Bates, the naturalist already referred to, called attention to mimicry as present among the butterflies of the Amazon region. Certain kinds, owing to their nauseous qualities, are rarely attacked by birds. Others, little related, and differing greatly in structure, resemble the immune kinds very closely, and so escape, although perfectly edible. This is called *Batesian* mimicry, to distinguish it from *Müllerian mimicry*, which was made known by Fritz Müller. In Müllerian mimicry different inedible species resemble one another, and it is supposed gain an advantage from the resemblance, because birds which have tasted one and rejected it will avoid the other at sight. These phenomena have given rise to a great deal of discussion, and opinions differ as to their interpretation. It has been pointed out that in several cases the supposed mimics do not fly in the same places as the forms they resemble, and it has been noted that the "protected" species do in fact suffer from the attacks of various

FIG. 104 *a*. *Agapema anona*, a moth of the family Saturniidæ, from Arizona.

FIG. 104 *b*. Cocoon of *Agapema anona*.

enemies. Broadly speaking, however, there can be little doubt that the facts are essentially as Bates and Müller indicated, although when we come to details there are complications and exceptions. The butterflies have been in course of evolution for a very long time, and what they are today depends very largely on conditions existing in the past, of which we have little or no knowledge.

Cases are known in which the "protected" butterflies, as though conscious of their immunity, fly in a slow and leisurely manner, almost inviting inspection. Their mimics, although belonging to another group, which usually flies rapidly, imitate the leisurely flight. It is a little difficult for us to believe, as we must believe, that this "bluff" is wholly unconscious.

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CHAPTER THIRTY-NINE

BEES

1. Bees are closely related to the digger wasps, and appear to have been evolved from them. So close is the resemblance, in certain cases, that it is difficult at first to see any distinction. All bees, however, have at least some plumed or featherlike hairs, while the hairs of the wasps are simple. Plumed or branched hairs occur also among the ants, but these are not likely to be confused with bees. The digger wasps capture insects of various kinds, and store them in their nests as food for the young. The bees, on the other hand, are vegetarians, and their maggotlike young feed on a mixture of honey and pollen. Certain kinds of bees are parasitic in the nests of others; these gather no pollen, but, depositing their eggs in the cells of industrious species, cause the latter unwittingly to support their offspring at the expense of their own. These parasitic bees are often gaily colored, sometimes resembling wasps, and are without the *scopa* or arrangement of pollen-collecting hairs seen in other species. Although they thus live at the expense of their neighbors, they prosper less than the working kinds, and are always relatively scarce. Indeed, were they to become excessively numerous, both they and their hosts would perish together, as would a human society, the majority of whose members got their living by stealing. **Origin and relationships of bees**

2. We do not know when the first bees came into existence, but very well-preserved examples, showing the characteristic mouth parts, are found in Baltic amber,[1] which is probably about two million years old. **Fossil bees**

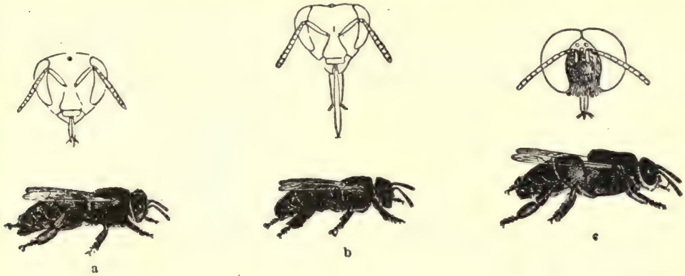
[1] Amber is a fossil resin, which when flowing from the trees entrapped and inclosed great numbers of insects and other small creatures. These are now preserved with all their most delicate parts, resembling specimens mounted in Canada balsam for the microscope.

Certainly the bees could not have evolved before the flowers, though it is likely that primitive flowers were not dependent on bees for the carriage of their pollen. In Africa it has been observed that cycads, a very ancient type of plants, are apparently pollinated through the agency of beetles; and we have fossil beetles of vastly greater antiquity than the earliest known bees. Bees are adapted to flowers in two ways: their mouth parts are so constructed that they can get nectar from the blossoms, and their hairs, or sometimes special surfaces on the legs, are suited for the collection of pollen or mixtures of pollen and honey. In the leaf-cutting bees and their relatives the under side of the abdomen is densely covered with stiff hairs, constituting the *ventral scopa*. Here is accumulated a mass of usually orange or yellow pollen, which, while destined for the young, also serves to pollinate the flowers which the bee visits. That is to say, some of the pollen gets detached and sticks to the stigma of the flower, leaving in every case sufficient for the next generation of bees. Thus the bee does not serve the flower alone, nor the flower the bee alone, but each gives to the other, — the bee service or labor, the flower material or capital. Other bees, serving the flowers in similar ways, carry the pollen on the legs, while even the hairs of the head may be dusted with the powderlike material. The humblebee has a smooth surface on the hind legs, fringed with hairs; this is known as the *corbicula* or pollen basket, and is a specialized structure for carrying moistened pollen. All the work is done by female bees; the male, often differing in appearance from the female, visits flowers and may accidentally carry a small amount of pollen, but he is a born loafer. His motto may well be, a short life and a

Adaptation to flowers

Habits of bees

merry one, for he has no functions which will justify old age. Thus the *Halictus* bees, which burrow in the



From "Animate Creation"

FIG. 105. The honey bee (*Apis mellifera*): *a*, queen (female); *b*, worker (sterile female); *c*, drone (male). The outline of the front of the head is shown above each form.

ground, hatch out male and female in the late summer. The males die, but the females survive the winter, and may be seen in the spring industriously making their nests, without any assistance from the other sex. In the case of the *Anthophora* bees, which construct holes in banks and are the cliff-dwellers of the group, the males may be observed to stand at the entrance of the tunnels. They are easily recognized by the largely yellow or white face, and it is this face which is exposed as their round heads fill the orifice. These males are in fact able to function as front doors, stepping aside whenever a female desires to enter. In the case of the social bees, such as the honeybee, there seems to be a third sex, the *worker*. The workers are, however, sterile females, while the drones are the males. The queen bee is the egg-laying female.

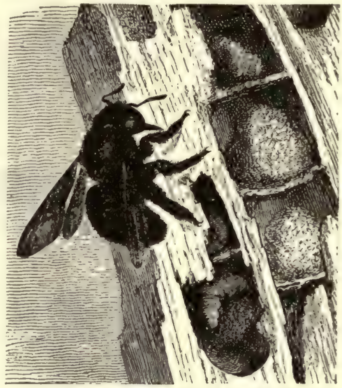
The sting

The males being comparatively worthless, it seems that Nature has not thought it worth while to protect them with a sting. Only female bees (including workers) can sting. The sting is a modification of the ovipositor

or egg layer of more primitive Hymenoptera, and hence on morphological grounds we could hardly expect to find it in males.

Various kinds of nests

3. The nests of bees are very diverse, according to the species. Very many burrow in the ground, but others nest under or on rocks, on trees, or in stems of plants. A group of very large bees (*Xylocopa*) works in wood, and has thus earned the name "carpenter bees." The pretty spotted bees called *Dianthidium* make nests of resin and pebbles; but their relatives, the species of *Anthidium*, collect woolly material from the stems of plants. The leaf-cutting bees (*Megachile*), found in almost every country in the world, cut semicircular pieces of leaves with their mandibles, and use these to line their cells. Frequently they use petals for the same purpose, though certainly not for ornament, as the young are reared in total darkness. The social bees, including the humblebees[1] and honeybees, have special wax-producing organs on the abdomen, and hence are able to make the cells in which their young are reared, without recourse to the support afforded by the walls of a tunnel. The comb of the humblebee is a complex structure, with receptacles for the larvæ (young), and others for honey and pollen. It is, however, a roughly and loosely constructed affair



From Brehm's "Thierleben"

FIG. 106. A wood-boring or carpenter bee (*Xylocopa*), with its nest. The latter is exposed by splitting open the timber in which it was constructed.

Honeybees and humblebees

[1] *Hummel* in German; "bumblebee" is a corruption.

compared with the beautiful comb of the honeybee, with its symmetrical six-sided cells. In the great group of

From Brehm's "Thierleben"

FIG. 107. A leaf-cutting bee (*Megachile*): *a*, female; *b*, male; *c*, a rose leaf with parts removed by the bee; *d*, a nest in a cavity in a plant stem; *f–i*, details of the construction of the cells of a nest; *k*, a pupa.

bees we find still preserved representatives of numerous stages of evolution, from the simple tunnel of the solitary bee, to the complicated nest, with no less complicated habits, of the most completely socialized kinds. The true honeybees (*Apis*) are confined to the Old World, except where they have been introduced by man. In the tropics of both hemispheres, however, are numerous species of stingless social bees (*Trigona* and *Melipona*), mostly of small size. Some of these, as if to make up for the absence of stings, have the power of emitting an irritating liquid, and are extremely pugnacious when disturbed.

Mouth structures of bees

4. Just as we find a series of types of nests, so also do we find in the mouth parts of bees a beautifully graduated series leading from the wasplike type to

the long-tongued species which visit tubular flowers. In some of the least specialized bees the tongue is very short and broad, and notched in the middle, indicating its primitively double nature. In others it is daggerlike, and by selecting appropriate species one may arrange a series with successively longer tongues until we come to certain tropical bees in which the tongue is actually longer than the body and when turned backward projects behind like a tail. On each side of the tongue are the four-jointed *labial palpi*. These palpi or feelers in the lower bees have four similar joints, but as the tongue elongates, so do the two basal joints of these palpi, while the two apical joints remain at the end, still small and unmodified. The *maxillæ* form external sheaths, and these too bear palpi, with the maximum number of six joints. In the higher bees these palpi seem unable to keep up with the elongation of the other mouth parts, and they become reduced to five, four, three, or two joints, or even disappear altogether. They follow the law that useless parts tend to become smaller, but usually remain as vestiges. It is also to be noted that, as in so many other cases, the number of parts (as joints of the palpi) may become reduced, but never increased over the primitive number.

Wings of bees

So, again, in the wings of bees we find specialization by reduction. The upper wing of a bee or wasp shows a thickening on the upper margin, called the *stigma*. This may be large, or almost absent. Just beyond the stigma is an inclosure, bounded by so-called veins, known as the *marginal cell*. Below the marginal cell are other inclosures, often more or less square, the *submarginal cells*. The usual number of submarginal cells is three, but there may be only two, and a small parasitic bee has only one.

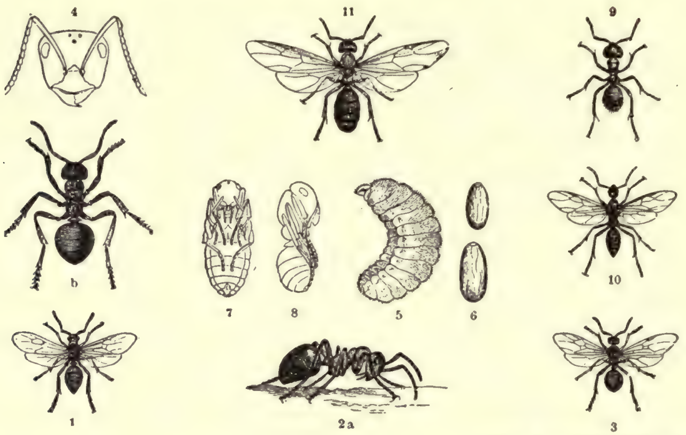
CHAPTER FORTY

ANTS

1. ANTS have always attracted the attention of mankind on account of their abundance, wide distribution, and social habits. They constitute a group of the order Hymenoptera, and are especially distinguished by the structure of the abdomen or hind body, which has one or two modified basal joints, forming nodes or scalelike structures. It will also be noticed that the antennæ are elbowed or sharply bent, superficially appearing as if broken. Nearly all ants exist in three forms, the male, female, and worker. The male and female have wings, but the latter removes her wings when she has been fertilized and is about to start a nest. The workers, which are sterile females, are entirely wingless. The sting in ants, bees, and wasps represents and is derived from the ovipositor which exists in more primitive groups. This ovipositor, or egg placer, naturally belongs to the female; hence male Hymenoptera do not sting. Among the ants, the workers of many genera, being modified females, can sting; but in many other genera this power is lost. **Characters of ants**

2. *Polymorphism* is the name given to indicate the existence of several different forms within the limits of a species. If there are only two forms, — for instance, two sexes differing in appearance, — we speak of *dimorphism*. When there are three forms, as male, female, and worker, the term *trimorphism* may be used. Beyond this comes *polymorphism*, from the Greek words meaning "many forms." We also use the adjectival forms *polymorphic*, *dimorphic*, *trimorphic*. Ants are often highly polymorphic. Frequently the workers differ greatly in size, and in some species there is a **Polymorphism**

group or caste known as soldiers, with enormous heads. These peculiar individuals, which occur especially in



From Brehm's "Thierleben"

FIG. 108. Ants. 1–8, *Formica rufa*: 1, male; 2 *a* and *b*, workers, much enlarged; 3, female; 4, head of worker; 5, larva; 6, pupa cases; 7–8, pupa. 9–11, *Camponotus herculeanus:* 9, worker; 10, male; 11, female.

the genus *Pheidole*, found commonly under stones, have brains no larger than those of their small-headed fellows. In some cases the differences between ants are due to special causes such as the presence of parasites, and do not come under the head of normal polymorphism.

History of the ant colony

3. The history of an ordinary ant colony is roughly as follows: At a certain time of year, differing with the locality and species, the functional sexes are produced. These are nearly always winged, and have the instinct to leave the nest, rising into the air for the marriage flight. During this period they are attacked by various enemies, but those which survive return to the earth, not to leave it again. The males die, but the females seek a place to found a nest, or sometimes

return to the nest from which they came. Not rarely one may find an impregnated female, or queen mother, recognizable by her large size, occupying a small cavity under a stone. She has removed her wings, as though to prevent all temptation to leave home and duty. She waits patiently for her eggs to mature, and at length lays them in a small group. From them hatch the larvæ or grubs, which are fed with a secretion produced by the mother. It may be months before this first brood has been produced and reared to maturity, and in the meanwhile the female not only takes no food, but feeds her young at the expense of her own substance. The individuals thus produced are small workers, and it is now their duty and occupation to go forth from the nest on excursions, to hunt for food for themselves and their exhausted parent. In this they are successful, being guided by suitable instincts, and when the queen is properly fed she proceeds to lay many more eggs. She may live to be fifteen years old, continually producing eggs, but after raising her first brood taking no more interest in the young. These latter are now fed by the workers, who assume all the duties connected with the colony, except that of producing eggs. With time, the nest or colony becomes more populous and more prosperous, and like a city, it appears to be able to continue almost indefinitely.

Ants' nests

The majority of ants nest in the soil, but many, especially in tropical countries, live in nests built in trees, or occupy cavities in the stems of plants or in galls. In Mexico and Central America we find acacia trees with remarkable enlarged thorns which are hollow and are inhabited by ants.

4. The ants are not the only inhabitants of their nests. Just as human habitations shelter domesti-

Animals which live with ants

cated animals and pets of various kinds, so the ants have associated with them a miscellaneous fauna, known collectively as *myrmecophiles* (Greek for "ant lovers"). A very common ant in temperate regions, known as *Lasius*, nests under rocks. In the spring and early summer, if we lift the rocks or stones scattered on a hillside, we shall probably find the nests, and be able to examine the more superficial galleries. We shall see, not only the ants, but frequently numerous small mealy bugs (*Coccidæ*) and plant lice (*Aphididæ*), which feed upon the roots of plants. The ants evidently regard them as their property, for they seize them with their jaws and hasten to carry them off to passages underground. The fact is that these insects secrete a sugary substance on which the ants feed; it is the same substance which, when produced by plant lice living on trees, falls on the leaves and is recognized as honey dew. The ants not only keep certain kinds of coccids and aphids in their nests, but make excursions to visit others which live on various plants above ground. In tropical countries the best way to find mealy bugs and scale insects (coccids) is to watch where the ants are going. If these animals are thus useful to the ants, how do the latter reciprocate? Just as man does in the case of his animals, — they give protection. Many wasps and other insects feed upon aphids and coccids, but should they enter an ants' nest they would at once be attacked. The protection above ground is not so complete, but collectors of coccids know to their cost that they are likely to have their hands attacked by stinging ants, while ants have been seen to drive away wasps which were seeking to provision their nests with aphids.

Other creatures in the nests are scavengers, still

others are parasitic on the ants, while many seem to take advantage of the protection afforded without having any special connection with ant life. Indeed, the ants appear to harbor useful animals, pets, scavengers, and camp followers of all kinds, just as we do.

Food of ants

5. Since the ants have domestic animals, have they any kind of agriculture? The more primitive ants are essentially carnivorous and, like savage peoples, live by hunting from day to day. We find, however, that various species, such as the bearded ants so common in the Southwest, have a system of harvesting. The ancient advice to "go to the ant" and study her wise prevision, has its basis in this fact. The small ants of the genus *Pheidole* gather many seeds; and, as Wheeler points out, the large-headed soldiers, with their powerful jaws, become the "official nut crackers of the colony." It was at one time supposed that some of these harvesting ants did actually raise crops, but this proved to be a mistake, and hence the term "agricultural ants," as applied to them, is a misnomer.

Leaf-cutting ants

Although we are obliged to deny all knowledge of agriculture to the harvesters, there is another group of ants which really do raise crops. In tropical America, and so far north as Arizona, the leaf-cutting ants are often observed carrying on their peculiar occupations. They nest in the ground, but come forth in long processions and, ascending the trunks of trees and stems of herbaceous plants, cut off leaves and carry them home. Sometimes they will even take small flowers, and appear as if carrying bouquets. In hot countries they are often called "parasol ants," because it is fancifully supposed that the leaves they carry seem to protect their heads from the sun. As a matter of fact the leaves are carried into the underground chambers,

Fungus gardens

where they are reduced to fragments and serve as culture beds for the growth of particular kinds of fungi or, as it were, miniature mushrooms. The fungus in each case starts from material brought by the queen founder of the colony from her home nest in a special pocket or pouch in the head. Each kind of leaf-cutting ant cultivates a particular species of fungus, and takes every precaution to keep the underground gardens free from contamination by useless sorts. Thus these animals have a genuine system of horticulture, with all regard for the principles of manuring, pure seed, and clean cultivation.

Honey ants

6. Ants not only store seeds, but there are some species which know how to put up preserves. The honey ants, especially to be found in the Southwest, have peculiar forms of workers whose function it is to serve as living honey jars. Many kinds of ants eat nectar and honey dew, and after storing it in some quantity in their crops, regurgitate it to feed the larvæ in the nests. The honey ants exhibit an extreme exaggeration of this function. Special workers, destined to be "repletes," are fed by the others while food is abundant, and the material accumulates in their abdomens. After a time the hind part of the body becomes swelled and globular, shaped like a pea and of about the same size. These repletes, thus filled with so-called honey, never leave the nest, and are to be found only by digging. The ordinary workers, long-legged and agile, go forth at night, and are quite unlike the repletes in appearance. In this strange manner food is stored up, to serve the whole colony in times of scarcity. It is a curious fact that this method of accumulation has developed quite independently in different groups of ants, in localities as far apart as North America and Australia.

7. Sometimes more than one species of ant is found in a given nest. When this is the case, the association may be one of essential equality, or it may be that one species has been captured by and works for another. The red ant known as *Formica sanguinea* (sanguinea, bloody) raids the nests of black ants of the *Formica fusca* group, and after a battle, carries away the larvæ and pupæ. The ants developing from these in the sanguinea nest live and work there along with their masters, and the effect of the raid is to increase the working population. *Formica sanguinea* has lost none of the instincts and powers of ordinary ants; it can live without slaves, although it rarely does so. Another sort of red ant, known as *Polyergus*, is in a very different position. It cannot exist without slaves, for although it is a great fighter, it cannot procure its own food. The large and remarkable mandibles are fitted for fighting and seizing other ants, but are wholly unsuited for any domestic purposes. There are many other ants, exhibiting various kinds and degrees of association, social parasitism, and slavery. Wheeler, reflecting on all these phenomena, is led to remark: "He who without prejudice studies the history of mankind will note that many organizations that thrive on the capital accumulated by other members of the community, without an adequate return in productive labor, bear a significant resemblance to many of the social parasites among ants. This resemblance has been studied by sociologists, who have also been able to point to detailed coincidences and analogies between human and animal parasitism in general. Space and the character of this work, of course, forbid a consideration of the various parasitic or semiparasitic institutions and organizations — social, political, ecclesiastical, and

Slavery

criminal — that have at their inception timidly struggled for adoption and support, and having obtained these, have grown great and insolent, only to degenerate into nuisances from which the sane and productive members of the community have the greatest difficulty in freeing themselves." (*Ants*, page 503.)

Analogies and differences between human and ant society

8. In spite of so many resemblances between the social life of ants and mankind, we must note some important differences. Ant society is conducted by the female sex, if we include in this term the sterile females or workers. The males are short-lived, and have no part in the affairs of the nation. Ants do not possess the "choice of good and evil," as do men. They appear to have some power of choice, but in the main they are governed by instincts, which hold them down to definite lines of conduct. Thus, as "free agents," it would seem that the slaves of the *Polyergus* might at any time go off and leave their useless owners to starve. This is, however, impossible; their instincts hold them more effectively than any chains. It must be confessed that although man is not thus tied down to the path of custom, he is very largely controlled by his habits and traditions. There are numerous situations in human society which ought to be considered intolerable and are only endured because people have neither the initiative nor the imagination to break away from them.

Ants also differ greatly from civilized man in that they have no idea of progress. The wonderfully preserved insect fauna of amber, perhaps a couple of million years old, includes thousands of ants. These show that there has been little or no progress in ant life and organization since that remote time. It must be remembered, however, that of the total period during

which the human species has existed, only a small portion, comparatively speaking, has been marked by any regular progress.

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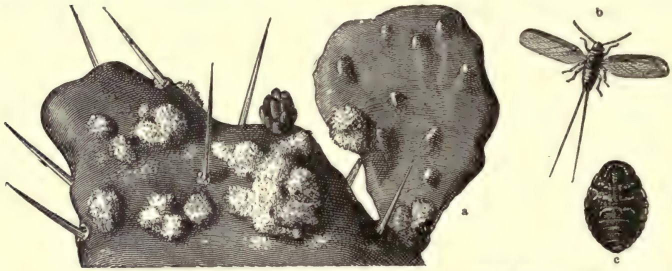
CHAPTER FORTY-ONE

SCALE INSECTS

Peculiarities of Coccidæ

1. Scale insects and mealy bugs, technically known as Coccidæ, constitute a group of Hemipterous insects,



From Brehm's "Thierleben"

Fig. 109. The cochineal insect: *a*, colony of the insects on a prickly pear plant; *b*, male; *c*, female.

but differ in remarkable ways from the other members of the order. From ancient times it was customary to utilize the coloring matter obtainable from certain small round objects found on oak trees in the region of the Mediterranean. They were regarded as berries (*kókkos*), or called by the Arabic name *kermes*. For many centuries the opinion that these objects were of vegetable origin prevailed, but in 1551 Quinqueran de Beaujeu published a book on the productions of Provence (France), in which he clearly explained that they were insects. The supposed berries, said he, were the female insects, which produced innumerable very minute "worms." The latter settled on the twigs, and grew into berrylike adults. With the discovery of Mexico, came the report by Francisco Hernandez and others that on the tuna, or prickly pear, existed a new sort of coccus, much to be preferred as a source of red dye. This, which came to be known as the cochi-

Kermes as a source of dye

nilla, or cochineal, was imported into Europe. The cacti on which it fed were brought over, to establish the cochineal industry, and these plants now abound in all the Mediterranean countries. So characteristic are the prickly pears today in the landscape of Greece and Italy, that artists depicting scenes of classical times sometimes put them into their landscapes, ignorant of the fact that these cacti are natives of America, and did not exist in Europe until brought over to feed the cochineal.

The cochineal

Other insects of the same group produce wax, while still others are the source of lac, which is used as a varnish. The wax and lac are not the insects themselves, but their secretions, which in life serve for protection. Lac coccids also yield a coloring matter, known as "lake"; while the name "vermilion" is derived from the vermes or "worms" developing in the kermes. All these coloring matters are now largely superseded by the coal-tar dyes.

Wax and lac

2. While the Coccidæ are thus beneficial, they also include species which are among the most dreaded pests of the fruit grower, while others injure ornamental plants. One of the worst of these pests was the cottony cushion scale (*Icerya purchasi*), which threatened to destroy orange culture in California, but was finally overcome by a beetle (*Novius cardinalis*), brought from Australia. The cottony cushion scale is about the size of a pea, and produces a white, fluted ovisac, containing the eggs. Vast numbers of these scales collect on the branches of trees, and suck the sap. These are the females; the male, not often noticed, is a small fly with two wings. When this creature came to be a pest in California, the entomologists found that it had first been described from New Zealand, but

The cottony cushion scale

How the orange trees in California were saved

was believed to have come from Australia. In Australia, however, it was not destructive. It was suggested that probably there existed in Australia one or more natural enemies, which devoured it as fast as it increased, and so kept it in check. It had reached America without these enemies, and had been able to multiply without hindrance. With some difficulty the Government authorities were able to send a man to Australia, on what must have seemed to many a wild-goose chase; but the result proved the correctness of the *a priori* opinions. Natural enemies of the scale were found in Australia and brought to America; and one of these in particular, a red lady-beetle, checked the plague and soon reduced the pest to comparative insignificance. Thus the "balance of nature," disturbed by man, was restored.

San José scale

3. Quite a different sort of coccid is the San José scale (*Aspidiotus perniciosus*). The Californian city of San José (pronounced *ho-say'*) gives its name to this notorious pest of orchard trees, but we now know that it came from Asia. The scale is very small, hardly larger than a pin's head, and is very hard to detect on the bark of a tree, unless massed in quantity. Scales of this type are therefore very easily carried about on trees, and escape observation until they begin to appear in the orchards as pests. On account of this, horti-

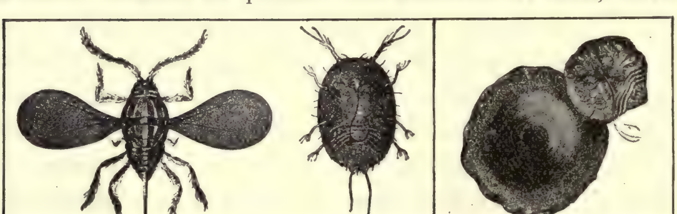


FIG. 110. San José scale, showing the winged male form, a larva, and a mature female with her protective scale; all much enlarged.

cultural quarantine officers are now stationed at various ports and examine all consignments of plants arriving. The number of injurious insects intercepted in this way is amazing, and much harm is prevented; though it seems hard to a passenger from Japan to have his highly prized little tree destroyed because it has scales on it which he himself cannot see at all! One needs entomological knowledge and a lively imagination to picture the possible evil which may come from such minute objects. The San José scale, which was brought in before the days of quarantine, represents the extreme type of Coccid development. The scale is like a little oyster shell, covering the minute fleshy female insect. This female has no legs or antennæ, but has a large mouth, designed for sucking the juices of plants. Her main function appears to be the production of young; she is inert, unable to move about, a picture of degeneration. The young are extremely small, oval creatures, with six legs and a pair of six-jointed antennæ. For a short time they can run about at will. They may be blown about by the wind, or may get from tree to tree on birds or insects. Their free time is short, and presently they have to settle down, for the rest of their lives if females, and begin to develop little scales. Some of them produce males, which are small, flylike insects with long antennæ and a pair of wings. The adult males have no mouth parts; they do not eat. Their sole function is to bring about the fertilization of the females, and this done, they die.

Evolution of Coccidæ

4. Thus the Coccidæ are exceptions to many rules. We say that insects have six legs, but many adult scale insects have none. We say that Hemiptera have four wings, but female coccids never have any, while the males have only two, or rarely none. How, then, do

we know that these creatures are insects and Hemiptera? We judge by the totality of their characters, and especially by the young stages, which repeat more or less the characters of their remote ancestors. In spite of their extraordinary character, there is no doubt whatever about their place in the classification. They are very instructive as examples of evolution by the loss of characters, accompanying a sedentary and more or less parasitic existence. The loss of wings finds its parallel in the lice and bedbugs, which are of course wingless in both sexes. In the different species of coccids there are all the stages between well-formed legs and antennæ, and none. In some the adult females are mere bags of eggs, and to classify them accurately we are obliged to examine the larvæ. The Coccidæ also illustrate in a very remarkable way *sexual dimorphism*. The two sexes of the San José scale, if examined by one unfamiliar with the group, might well be placed in different orders of insects, — the female immobile and without legs, antennæ, or wings, but with a highly developed mouth; the male of an entirely different shape, with legs and antennæ, a pair of large wings, and no mouth whatever! It is amazing that the germ cells of this species should be able to produce such totally different organisms. We are led to think of the possibilities inherent in living beings, but perhaps sometimes never realized. There is one species, the mussel scale of the apple, which reproduces parthenogenetically and only very rarely produces males. Suppose that all coccids developed this characteristic, and no males were ever produced; who could ever guess that locked up in the germ cells of the female was the potentiality of a being unlike her in almost every respect!

Sexual dimorphism

CHAPTER FORTY-TWO

GRASSHOPPERS AND THEIR RELATIVES

The Orthoptera

1. The order Orthoptera (Greek, straight-winged) derives its name from the straight or nearly straight upper margin of the front wings or tegmina of many locusts and grasshoppers. The Greek word *orthos* appears also in "orthodox," used to designate straight or strictly correct opinions. The name, as applied to the various insects now classed as Orthoptera, is ill-chosen, since many have rounded wings, while many others lack these organs altogether. We here accept the order as limited by the earlier authors, but it actually contains very diverse elements, and various efforts have been made to subdivide it. In the most modern classification the order is restricted to the locusts, grasshoppers, and crickets, the cockroaches and other groups being removed from it.

Ancient Orthoptera

When we look for evidence on this point in the rocks, we find that insects of the orthopterous type are extremely ancient, being abundantly represented in the rocks of the Carboniferous age, which are probably not less than 15 million years old. At the time when the material which later became anthracite coal was laid down in Pennsylvania and adjacent states, cockroaches were the dominant insects. They were of large size and varied structure, and found food and shelter in the luxuriant forests of primitive vegetation. During the same period there also existed insects, large and small, which are grouped together under the name Protorthoptera, or beginning Orthoptera. Some of these superficially resembled our modern katydids, and had spots on the wings, as may be seen in the fossils so wonderfully preserved in nodules at Mazon Creek,

Illinois. Thus, at this very early period, the true Orthoptera were in process of evolution, while the cockroaches had already started on a separate path of their own. When we see a cockroach, however little we like its appearance or odor, we owe it a certain respect, as belonging to one of the very oldest families in the land.

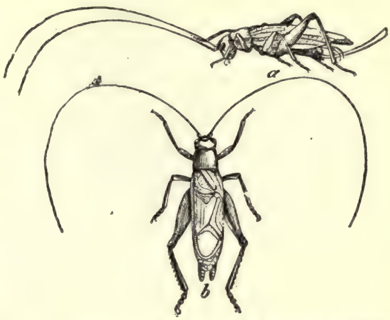
Insect music

2. The true or typical Orthoptera nearly always have the hind legs enlarged, and consequently the power of jumping; they also chirp in various ways, and appear to have been the inventors of music, coming into existence long before there were any singing birds. Their cries differ greatly according to the species,

From Brehm's "Thierleben"

FIG. 111. A group of cockroaches, showing individuals in various stages of growth.

and experts can often distinguish between closely related forms by their voices. It is also found that the sound proceeds from quite different parts of the body in different kinds; it may be the legs, the tegmina, or the abdomen. In no case, of course, does it come from the mouth, as with us. Various students have tried to record orthopterous songs in musical notation, and in so doing have brought out some interesting features. In some cases we find simply the monotonous repetition of a single note; but in others there is a regular variation, the sound rising and falling to produce true rhythm. Sometimes the song is in such a high key that it is inaudible to some human ears, though seeming loud to others.



From Bulletin 67, U. S. National Museum

FIG. 112. A tree cricket (*Orocharis*): *a*, female; *b*, male.

3. As might be expected in such a primitive group, the mouth parts are adapted for biting, not for sucking; and the metamorphosis is "incomplete." By the latter expression we mean that the infant grasshopper, on hatching from the egg, is visibly a grasshopper — not a grub, maggot, or wormlike animal. It is remarkable — as is the case with human infants — for the relatively large size of its head, and it has no wings. At this early period of its life it can hop well, but it is entirely mute. The grasshoppers' children literally obey the injunction that they should be seen but not heard. In many cases they avoid even being seen, owing to their close resemblance to inanimate **Mouth parts**

objects. As the grasshopper grows, wing pads appear, and the insect is said to have reached the pupa stage. The tegmina or superior wings appear as small, more or less triangular objects, with the anterior or costal margin upward; whereas in the adult the costal margin is downward when the insect is at rest. In this way it is easy to distinguish a pupa from the adult in those species which have the adult wings small and functionless. In the great lubber grasshopper of the Western foothills and plains there are no wings, nature having seemingly given up the effort to support the vast body in the air. The winged locusts and grasshoppers are often remarkable for the bright colors — red, blue, or yellow — of the hind wings. They are thus conspicuous in flight, and the question has naturally been raised why they should be so brightly colored, seeming to attract the attention of their enemies, the birds. It is noteworthy, however, that when pursued they settle on the ground, doubling back a short distance at the moment of alighting. When thus at rest, with the bright colors concealed, they so perfectly resemble the surface of the earth that the puzzled entomologist often searches for them in vain, though he thought he saw them alight. It is even to be noted that particular varieties agree in color with the rocks; thus along the front range in Colorado, where the disintegrating Carboniferous rock produces red soil, the hoppers are red to correspond. The bright under wings exposed in flight actually serve to puzzle the enemy, who has formed a mental image which suddenly disappears.

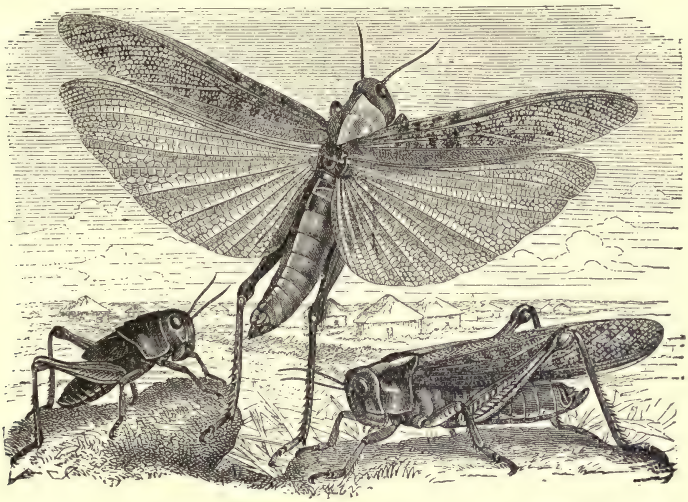
Colors of locusts

Protective coloration

Grasshoppers and locusts

4. Naturalists are often asked how to distinguish a grasshopper from a locust. There is no essential difference, but the far-famed locust of Egypt is remarkable

for its large size and its powers of flight. There are many species of these large locusts, which migrate in



From Brehm's "Thierleben"

FIG. 113. The migratory locust of the Old World (*Pachytylus migratorius*).

vast swarms and sometimes are met with at sea, hundreds of miles from land. The Rocky Mountain locust, on the other hand, is a relatively small insect, which when observed singly would always be regarded as a mere grasshopper. In former times this species used to migrate in incredible numbers, utterly destroying the crops. It is improbable that such great plagues of grasshoppers will ever again occur in our country; for the territory in which they bred has been mainly turned into farms, and the plowing of the land destroys the eggs. Our abundant and troublesome grasshoppers today are almost entirely resident or nonmigratory forms, and these will be diminished in number as more land passes into cultivation. **Rocky Mountain locust**

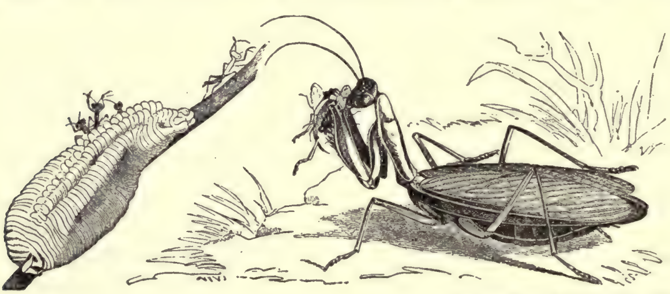
Stick and leaf insects

5. Somewhat related to the locusts are the Phasmidæ, or stick insects and leaf insects. Many are so extraordinarily like dry twigs as to be very hard to detect, while others, with broad, green wings, almost perfectly resemble leaves. In the early days of exploration, sailors used to tell how, in certain tropical countries, the leaves fell off the trees, but crawled back to their places. Such apparently gratuitous lies were in fact founded on observation, as is the case with many other strange tales of travelers.

Rather similar to the phasmids, but structurally very distinct, are the Mantidæ or soothsayers. In this group the front legs are curiously modified, and are held, as it were, in an attitude of prayer. Consequently the common species of the Mediterranean region

The praying mantis

(*Mantis religiosa*) has been regarded as a sacred animal, and is known as the "praying mantis." As a matter of fact, its apparently pious attitude merely indicates readiness to spring upon its prey, as a cat springs upon a mouse, and the voracious creature should properly be called the "preying mantis." The mantids are so peculiar, that one might well suppose them to be of relatively recent origin, but the evidence of the fossils indicates that they are extremely ancient. Like the



From Brehm's "Thierleben"

FIG. 114. A praying mantis, its egg mass and recently hatched young.

cockroaches, they place the wings over the abdomen when at rest.

Cockroaches

6. The cockroaches or Blattidæ constitute a large group of insects, most abundant in the tropics. One species is extremely common in houses in England, where it is known as the black beetle, although it is dark brown, and is not a beetle. In Central America some of the cockroaches are over 3 inches long and fully 1¾ inches broad. These are repulsive creatures, but there is a small, delicate green species, often found in bunches of bananas, which is rather attractive. Superficially, cockroaches seem to have no head, that member being hidden under the large thoracic plate. The broad wings, with very numerous veins, are folded over one another across the back, presenting a flat surface from above. The hind legs are not adapted for jumping, nor are there any musical organs. The long, slender antennæ have very many joints. Cockroaches were abundant in later Paleozoic times, many millions of years ago. A fossil wing is figured on page 151. Forty-three living species of cockroaches are known from the United States, but they are mostly Southern, and ten have probably been introduced through human agencies.

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CHAPTER FORTY-THREE

PROCHORDATA AND CYCLOSTOMES

The notochord

1. THE vertebrates are distinguished from invertebrates by the possession of a vertebral column. That is to say, they possess a so-called backbone, which consists of a great number of bones, the vertebræ, arranged in a series. Prior to the development of this structure, in the very early embryo of all vertebrates, appears a rodlike element known as the *notochord.* It is not cartilage, and does not become bone, but it occupies the place of the subsequently developing vertebræ, and has an essentially similar function, that of stiffening the animal.

Dorsal nerve cord

In all vertebrates the main nerve cord is dorsal; that is to say, it is on the upper rather than the lower side of the animal, being just above the notochord. In invertebrates the reverse is true, so that we may say that the orientation or position of the vertebrates is reversed as compared with the invertebrates.

Breathing by means of gills

Vertebrates breathe in different ways, terrestrial forms and aquatic ones derived from them (as whales) having lungs, while primitively aquatic groups possess gills. The gills are, however, very different from those of invertebrates in the majority of instances, although the function of absorbing oxygen from the water is the same. The young of the lowest types of fishes, and even the adults of certain amphibians (such as the *Necturus* or mud puppy), possess external gills, which correspond in general structure to those of many invertebrates. We find, however, that in adult fishes there is another type of gill, which consists essentially of an arrangement whereby water, entering through the mouth, passes out on each side through the gill

clefts, between the branchial arches. Animals cannot break up the molecule of water (H_2O) and take the oxygen; they have to depend on the small amount of that gas which is dissolved in the water. Consequently, if the breathing apparatus is not very adequate, they may have to live near the surface or in running water. Various insect larvæ with external gills, which live in running streams, perish from suffocation if placed in a dish of still water. Now the gill-cleft arrangement is one for creating a stream, which flows continually past delicate tissues full of blood, which are at the same time largely concealed and protected from injury. It is evidently an advance in mechanical organization, — an invention of Nature, as it were.

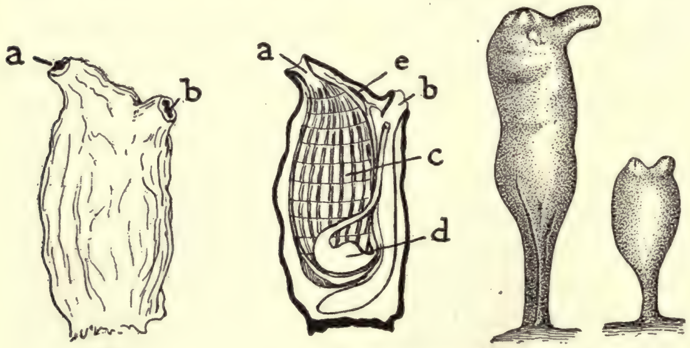
The Prochordata

2. These being the more fundamental characters of the vertebrates, we naturally ask ourselves, whence did they come? Are they wholly peculiar to these animals? Seeking an answer to this question, we come upon a series of animals which certainly are not vertebrates, because they possess no vertebral column; yet they possess, in greater or less degree, the notochord, the dorsal nerve cord, and the gill-slit apparatus. These creatures belong to entirely distinct groups, typified by the Amphioxus, the Balanoglossus, and the tunicate or sea squirt. All are marine, and of comparatively small size. This series of animals, thus set apart from the vertebrates and invertebrates alike, is grouped under the name Prochordata, mainly as a matter of convenience. It is not certain that some of the characters mentioned may not be found or have existed among the invertebrates; thus Professor Patten of Dartmouth College describes a notochord as existing in a scorpion. In his opinion the scorpions (a very ancient group, certainly) are the survivors of the gigantic Eurypterids

of early Palæozoic times, and these Eurypterids he thinks may be the ancestors of the curious extinct creatures called "Ostrocoderms," which seem to lead toward the true vertebrates. However this may be, no one sees in the living Prochordates the actual types which gave rise to the vertebrates, but only animals possessing some of the characters which those ancestors must have possessed. They show us, in some measure, how the evolution may have taken place, and represent the unprogressive remnants of a group, most of which either died out entirely or evolved to higher things. They are therefore far more interesting than their undistinguished superficial appearance would suggest.

Tunicates

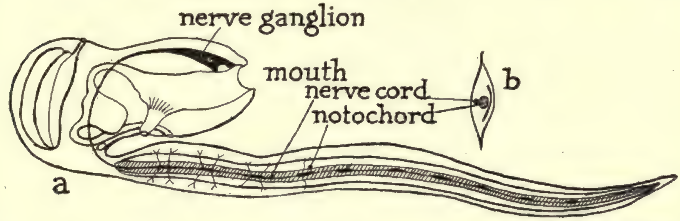
3. The *Tunicata* or *Ascidians* are marine animals which in the adult state appear under a variety of forms, some attached to rocks, others floating in the open sea. The name "tunicate" is derived from the tunic or coat forming the outer layer of the animal. The commoner species, known as "sea squirts," are found attached to rocks; when irritated they rapidly



Drawings by W. P. Hay and R. Weber

FIG. 115. 1, lateral view of an ascidian, and 2, a diagram of its anatomy. *a*, incurrent orifice; *b*, excurrent orifice; *c*, branchial basket; *d*, stomach; *e*, nervous system. 3, another species of ascidian (*Styela*).

contract, emitting a stream of water. The mouth leads into a large sac, the pharynx, the walls of which



Drawing by W. P. Hay

FIG. 116. Diagram of the anatomy of *Appendicularia,* one of the *Larvacea:* *a,* lateral view; *b,* cross section of tail.

have a more or less latticelike structure, with many small openings. This is the gill apparatus, and the water passing through it gives up its dissolved oxygen to the blood. At the end of the pharynx is the opening of the alimentary canal. The pelagic or free-swimming Tunicata are very different — more or less cylindrical, and transparent. Some are quite large, others minute. These animals were formerly associated with the Mollusca and regarded as a sort of shell-less clams, but the investigation of their immature stages showed the entire error of this view. The larva or young stage is a more or less tadpolelike creature, with a long tail containing a notochord. In development, all this gradually disappears by absorption, except in a group of minute free-swimming forms constituting the class *Larvacea*, which retain the elongate form and notochord through life. In addition to the characters mentioned, the tunicates have a dorsal nervous system, so that in several important respects they are to be associated with the vertebrates rather than with the typical invertebrate animals.

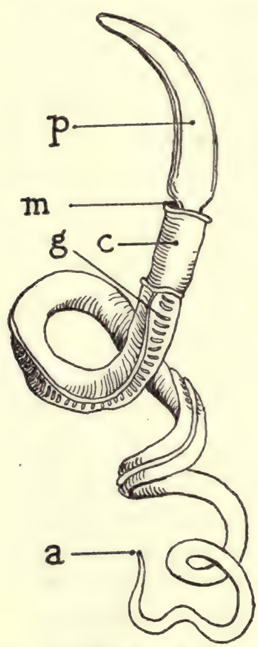
The larval tunicate

It is commonly said that the tunicates exhibit degeneration. This is not quite exact, but it is true that after seeming in the early stages to promise develop-

ment leading to a vertebrate type, they belie all such expectations and change into a creature of relatively simple structure and limited activities. They become specialized in a new direction, and although they are efficient and anything but degenerate in their own particular line, it is impossible for us, who represent the culmination of the other alternative, to regard them without a certain sense of disappointment, almost of reproach. It is also apparently true that following their special line, they have abandoned all possibility of extensive and varied evolution in the future.

Balanoglossus

4. The *Balanoglossus* is a wormlike animal found in sand or mud or under rocks in the sea, not far from the shore. This general type includes a number of genera and species, differing in size, color, and various anatomical details. Some are orange, others greenish or purplish. The name *Balanoglossus* or "acorn tongue" is derived from the more or less acorn-shaped proboscis or head-like structure at the anterior end, which is used in burrowing. Posterior to this is the collar, at the anterior end of which is the mouth, leading into a pharynx with gill slits. At the anterior end of the digestive tract, projecting into the proboscis, is a small structure regarded as a notochord. Hence the animal must be associated with the Prochordata, although wholly



Drawing by W. P. Hay

FIG. 117. *Balanoglossus: p*, proboscis; *m*, mouth; *c*, collar; *g*, gill slits; *a*, anus.

unlike any vertebrate type in most of its characters. The larva or first stage is minute and transparent, and forms part of the plankton, or floating fauna of the sea. It has no resemblance to the adult, but does recall the larva of the Echinoderms, — a fact of considerable interest, because many naturalists suppose that the whole prochordate series, leading in one direction to the vertebrates, may have come from an animal which belonged to the same group as the ancestors of the starfish and sea urchins.

5. The *Amphioxus* (more correctly called *Branchiostoma*) derives its name from the fact that it is sharp at both ends. The name is used for any one of several similar species which burrow in the sand in shallow bays. They are pallid creatures, shaped like a small fish, the largest about 4 inches long. Of all the Prochordates, they show most vertebrate characters. They have a dorsal nerve cord, but no skull or brain; a well-developed notochord, but no vertebral column; a pharynx with gill slits, which do not, however, open on the surface of the body, but lead to a chamber **Amphioxus**

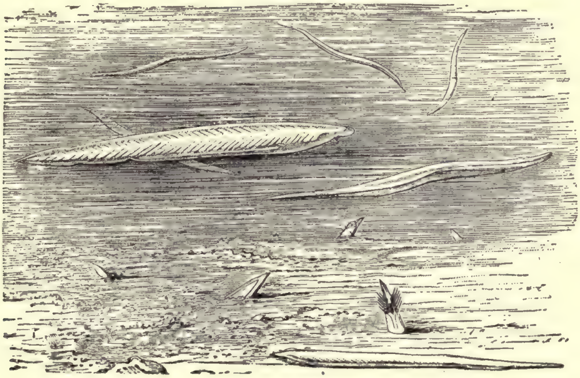
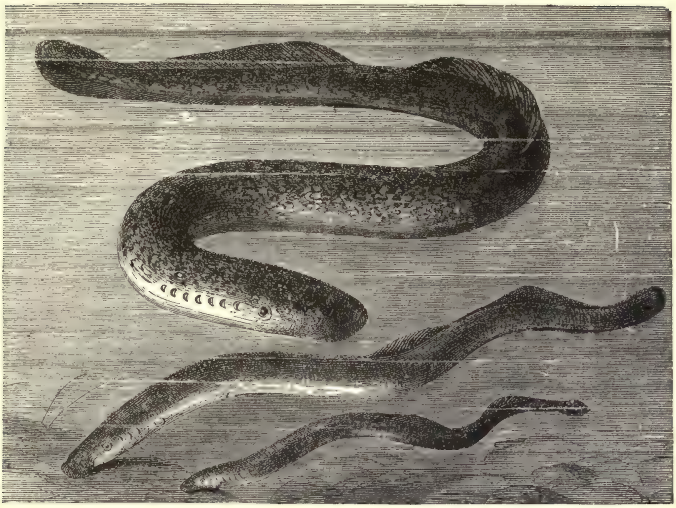


FIG. 118. Amphioxus (*Branchiostoma lanceolatum*).

through which the water passes, eventually escaping through a median aperture. The mouth, surrounded by long, whiskerlike cirri, is on the under surface, and is without jaws. The alimentary canal possesses a diverticulum or sac which constitutes a primitive liver, and represents the stage of development of that organ found in the early embryos of vertebrates. There are pigment spots on the dorsal nerve cord which appear to be primitive organs of vision, while a pit at the anterior end seems to represent the beginning of an organ of smell. Finally, the muscular tissue of the animal is segmented (the divisions are called "myotomes"), apparently the beginning of that segmentation which in vertebrates finds expression in the vertebræ with their attached ribs. Thus it seems that the intercostal muscles, which in ourselves lie between the ribs and serve to expand the chest in breathing, are actually more primitive than the ribs supporting them. The Amphioxus, therefore, though not a vertebrate, represents a very remarkable approach to the vertebrate type, and does not show the so-called degenerate features of the other prochordates.

Cyclostomes; the lampreys and hagfishes

6. The next stage in evolution, so far as known to us, is represented by the *Cyclostomes* ("round-mouths"), including the lampreys and hagfishes. These are not prochordates, neither are they true fishes. They possess a primitive but genuine brain, with a cartilaginous skull. The notochord is enveloped in a sheath, but there are no distinct vertebræ. There are paired eyes, but the nostril is single and median. There is no lower jaw, and there is no trace of paired fins. The liver is of the same general type as that of vertebrates in general. Lampreys live in the sea or in fresh water, and feed on the flesh and blood of fishes. The peculiar



From "Animate Creation"

FIG. 119. Lampreys.

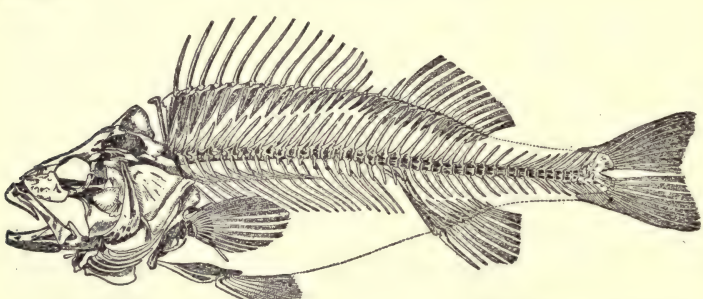
round mouth acts as a sucking disk, and enables the lamprey to hold on to the side of a fish, while it rasps the flesh with its horny teeth. Fishes with soft scales are most likely to be attacked, and dense, hard scales serve as a protection. The hagfishes, which are marine, actually burrow into the bodies of fishes and become parasitic. In very ancient rocks in Scotland there has been discovered a small fossil animal which in many ways resembles the cyclostomes, having a skull but no jaws or limbs, but possessing distinctly formed vertebræ. This extinct form, known as *Palæospondylus*, suggests that the cyclostome type is a very old one, although we know next to nothing about its history. The hard, porcelainlike scales of many ancient fishes may have been developed partly as a protection against these predatory creatures.

CHAPTER FORTY-FOUR

THE STRUCTURE OF THE VERTEBRATES

The vertebrate skeleton

1. VERTEBRATE animals may be defined as those possessing a vertebral column; but as we have already seen, they possess other important characters, some of which are shared by types lower in the evolutionary series. The *skeleton* of a vertebrate, or endoskeleton (internal skeleton), consists of numerous separate parts, which support the muscular and other tissues of the body, and protect the more important organs, such as the brain, heart, and lungs. In the lowest vertebrates, such as the sharks, the skeleton is wholly cartilaginous, consisting of gristle which can be easily cut with scissors or knife. In the bony fishes, such as the salmon or perch, and in all the higher vertebrates, hard bone is formed. This bone, however, is laid down in cartilage, or sometimes (e.g., the flat bones of the skull) in membrane, being formed by cells which secrete lime salts. Thus even man has first a cartilaginous skeleton, and it is only in the course of development that it is replaced by bone. The process of becoming bone is called *ossification.*



From Zittel's "Palæontologie"

FIG. 120. Skeleton of a perch, showing a loosely articulated skeleton of a relatively primitive kind.

The vertebral column

2. The bones consist of the *vertebræ*, the *skull*, and the *pectoral* and *pelvic* girdles with their appendages, the *limb bones*. To the vertebræ are directly articulated the *ribs*, which in the higher groups join the breast bone or *sternum* on the ventral side. In fishes and snakes there is no sternum. A few other bones occurring in various animals are not directly articulated to the main skeleton. The replacement of the dorsal elastic rod by bone necessitated the formation of separate pieces or vertebræ; otherwise the then aquatic animal would have been unable to swim with any success. On the functional side the case is parallel to that of the arthropods, which developed separate rings in their hard chitinous exoskeleton — as seen, for example, in the centipedes. A typical vertebra consists of a *centrum* or main body, from which arises above the *neural arch*, inclosing the neural canal, containing the spinal cord. The *spinal cord* is developed in the embryo round the primitive groove (the central canal which it contains is a relic of this), and thus belongs to the *ectoderm* or outer tissue. The vertebral column, on the other hand, has quite a different origin, from the *mesoderm* or middle tissue, but in the course of development it surrounds and incloses the cord. In many fishes the notochord remains between the vertebral centra, which may then be deeply excavated in front and behind; such vertebræ are called *amphicœlous*. In addition to the characters mentioned, vertebræ frequently exhibit well-marked dorsal spines and transverse or lateral processes.

The skull

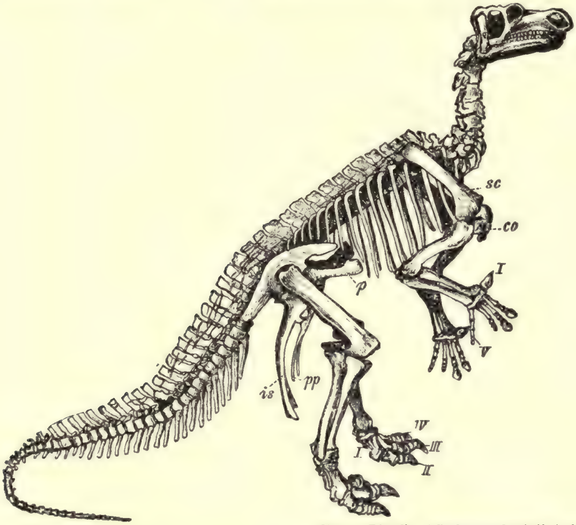
3. The *skull* consists of a number of bones, which are for the most part firmly articulated together. The *mandible* or lower jaw, which is movable, is not primitively part of the skull at all, but is derived from the

first gill arch, which swings into position in the course of development. Thus it may be said that our possession of a lower jaw depends on the fact that our ancestors were aquatic. The exact number of bones in a skull depends upon the amount of fusion and modification which takes place in development. Thus in the upper jaw of man there is no separate piece (the premaxilla) in front, except at an early age. This part completely fuses with the main body of the jaw; but in various other animals it is permanently distinct.

Pectoral and pelvic girdles

4. The *pectoral* and *pelvic* girdles serve for the attachment of the anterior and posterior limbs respectively. In the lowest fishes (sharks and rays) the girdles are represented by cartilaginous structures of simple form, but in higher vertebrates they are more complex, and are represented by several different bones. In man we recognize a *scapula* or shoulder blade, and *clavicle* or collar bone, forming the pectoral girdle. The clavicle is not present in all animals; thus in the ungulates or hoofed animals it is absent. This absence is evidently due to the loss of the structure, and it has been reported that traces of it may be found in the embryo of the sheep. On the other hand, the *scapula* is compound, consisting primitively of more than one bone. Near the concave surface for the articulation of the first bone of the arm is a process which seemed to the anatomists of olden times (who possessed a very lively imagination!) to resemble the head and beak of a crow (*corax*). Hence they called it the *coracoid process*. Later on it was discovered that in various vertebrates (e.g., birds) the coracoid process is represented by a large and important bone, to which the name *coracoid bone* was given. This coracoid bone represents in fact the ventral portion of the primitive pectoral arch, joining the

sternum at its median end. The clavicle is accessory to the main arch. In the domestic fowl the coracoid



From Zittel's "Palæontologie" (after Dollo)

FIG. 121. Skeleton of ***Iguanodon***, an extinct reptile belonging to the group of Dinosaurs, found fossil in Belgium. The skeleton is much more highly specialized than that of the fish, the shoulder and pelvic girdles being fully developed. *sc*, scapula; *co*, coracoid bone; *p*, pubis; *pp*, postpubic process; *is*, ischium; *I–V*, digits.

can be seen as a relatively thick bone on each side attached to the breastbone, while the united clavicles constitute the wishbone.

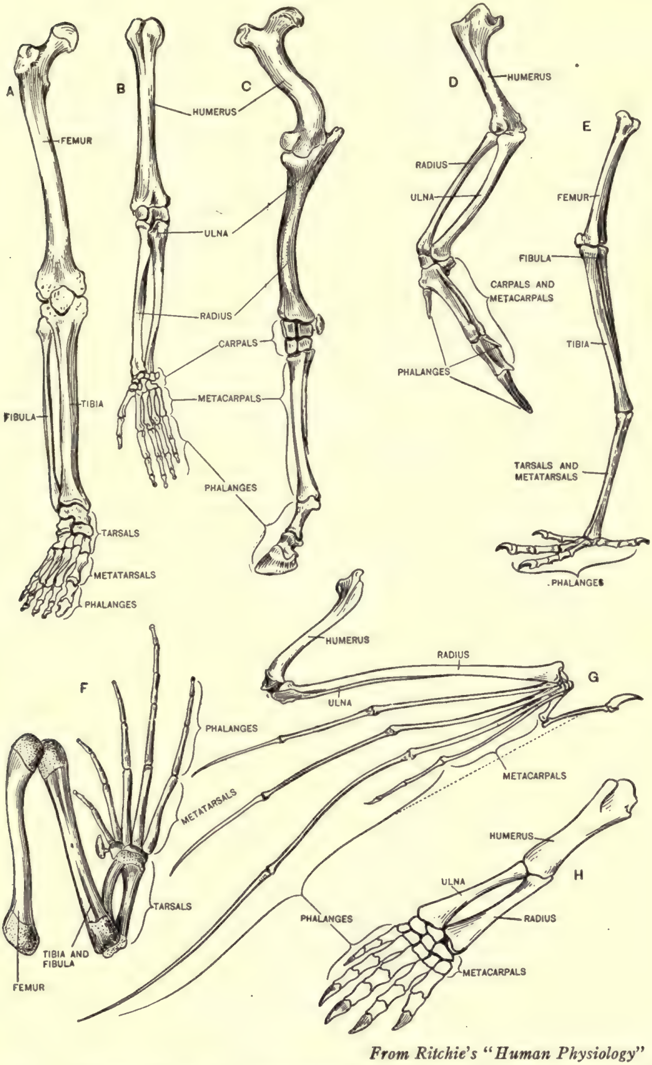
The pelvic girdle consists of homologous parts, except that there is nothing to represent the clavicle. It becomes firmly attached to the ribs, and is in man a very solid structure, to afford support to the hind limbs. The cavity for the articulation of the thigh bone or femur is much deeper than that for the arm bone, and is called the *acetabulum* or vinegar cup, because it more or less resembles the vessel used on the table to hold vinegar in ancient times. The flat portion of the pelvic girdle, corresponding to the scapula, is called the *ilium*.

The limbs 5. The limbs originate as paired fins. In the limbs of fishes we find a series of bones, supporting a large number of *rays*. In the terrestrial vertebrates the number of parts is reduced and, as it were, stereotyped, so that five is the typical and maximum number of toes or *digits*. In the frog the hind foot has a rudimentary sixth toe, a relic of the earlier condition when these parts exceeded five. Occasionally in man and other animals an extra digit appears as an abnormality. In the horse, on the other hand, there is only a single functional digit on each foot, the enlarged toenail being the hoof.

The anterior limb In the anterior limb the first long bone, articulating with the scapula, is the *humerus*. It is followed by two less robust bones, side by side, the inner being the *radius*, the outer or posterior the *ulna*. We commonly feel our pulse in the radial artery, close to the lower (distal) end of the radius. In the wrist is a group of small bones, collectively known as the *carpus*. The more primitive carpus (as in the turtles) consists of a central bone, the *os centrale*, three basal bones, and five apical, the last standing at the bases of the five digits. In man the three basal bones are preserved, but the centrale has disappeared, and the fourth and fifth of the apical row have united to form the *unciforme*. The accessory *pisiform* (pealike) bone has nothing to do with the primitive carpus.

Following the carpus is the series of five digits. The first bones (in ourselves supporting the palm of the hand) are called *metacarpals;* the others are the *phalanges*.

The posterior limb In the posterior limb we have corresponding parts: the first long bone is the *femur;* then follow the *tibia* and *fibula* (the tibia being the stout shin bone). The small bones of the ankle are collectively called the *tarsus*, and



From Ritchie's "Human Physiology"

FIG. 122. Vertebrate limbs. *A* is the human leg; *B*, the human arm; *C*, the fore leg of a horse; *D*, the wing of a bird; *E*, the foot of a bird; *F*, the hind leg of a frog; *G*, the wing of a bat; *H*, the fore leg of a tortoise.

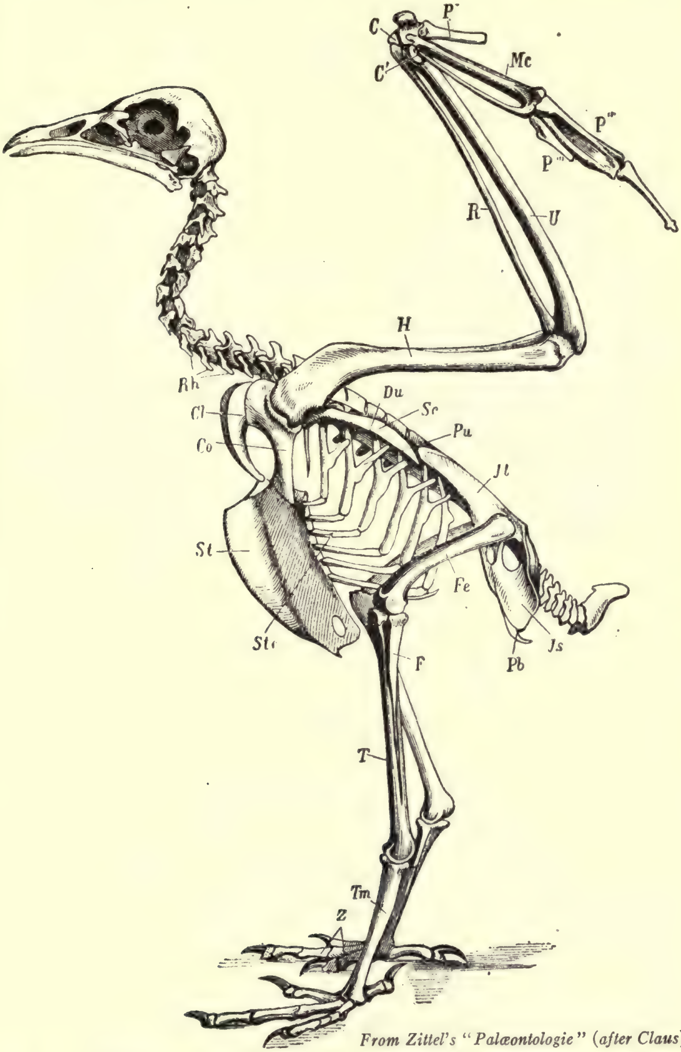
beyond these are *metatarsals* and *phalanges.* Man is peculiar for walking on the whole series from the tarsus on — the largest of the tarsal bones, the *os calcis*, forming the heel. When he "trips it on the light fantastic toe" he reverts to the posture of a remote ancestor.

The alimentary canal

6. The *alimentary canal* or digestive tract of vertebrates does not differ fundamentally from that of all but the lower invertebrate animals. Even the sea urchins and starfish have such a canal, with the same two openings for the entrance of food and the ejection of waste, respectively. The stomach is simply an enlargement of this canal, provided with special glands which secrete the gastric juice. The liver, primitively a pouch or sac arising from the digestive tract, becomes a large and complicated organ. Even the lungs originate in the same manner, and are at first simple sacs. At the anterior end of the alimentary canal, in the mouth, we find the teeth. It can be seen in the sharks that the teeth are structures of the skin, not differing essentially from the spines which may be found on the outer surface of the animal. The number at first is very great, but as evolution proceeds they are reduced and specialized, and become firmly attached to the jaw bones. Extreme types of specialized teeth, like those of the elephant and the horse, seem to have little in common with the simple conical structures of many fishes and reptiles. Many invertebrates possess teeth of different kinds, but these are not homologous with those of vertebrates.

The nervous system

7. In all vertebrates there is a *brain*, serving as the chief controlling center of the nervous system, and therefore of the whole body. The smaller nerve centers, called *ganglia*, are relatively very unimportant. The brain is continuous with the *spinal cord*, and both emit a series of nerves which branch and extend to every part



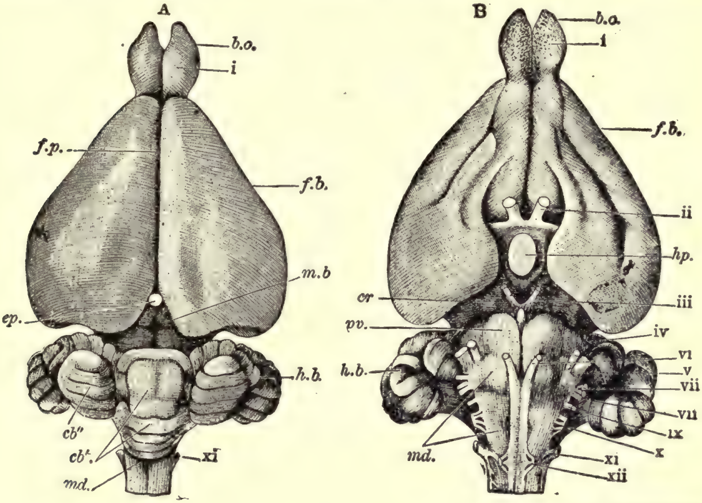
From Zittel's "Palæontologie" (after Claus)

FIG. 123. Skeleton of an Egyptian vulture. *Rh*, cervical vertebræ; *Du*, thoracic vertebræ; *Cl*, clavicle; *Co*, coracoid bone; *Sc*, scapula; *St*, sternum; *Il*, ilium; *Is*, ischium; *Pb*, pubis; *H*, humerus; *R*, radius; *U*, ulna; *CC'*, carpus; *Mc*, metacarpus; *p'*, *p''*, *p'''*, phalanges of the three digits; *Fe*, femur; *T*, tibia; *F*, fibula; *Tm*, tarsometatarsus; *Z*, toes.

of the body. These nerves are different in function; *afferent* or sensory nerves convey impulses to the brain or cord; *efferent* or motor nerves convey them in the reverse direction, and are the means whereby muscular activity is stimulated.

Primitively the brain is a swelling at the anterior end of the spinal cord, and in the course of evolution it becomes divided into three vesicles known as the fore-, mid-, and hind-brain. These vesicles are hollow, and the cavities become variously modified. The fore-brain gives rise to the *cerebral hemispheres*, which in man occupy most of the surface of the brain. Anteriorly the *olfactory lobes*, connected with the sense of smell, are developed. The upper and side parts of the mid-brain form the *optic lobes*, having to do with the sense of sight. The hind-brain forms the *cerebellum* (little brain) anteriorly and the *medulla oblongata* posteriorly — the latter directly continuous with the spinal cord. If we take any one of the lower vertebrates, such as a fish or a frog, we find the organs of *immediate sensation* well developed, but that part of the brain which keeps the record of past experiences is very small. In man, on the other hand, the part connected with memory and reflection is very large. Thus the lower vertebrates act almost wholly in response to stimuli just received, whereas man's actions depend on past as well as present experiences. It is possible to predict exactly what a fish will do under given circumstances, almost as though it were a mere machine. One cannot make similar predictions about a man, except in the case of actions still brought about by reflexes which are not under the control of the brain. Such reflexes are observed in *tickling*, which may produce irresistible kicking or coughing according to the part stimulated. Others, like those pro-

ducing movements of the stomach, do not rise into the field of consciousness. Thus we have: (*a*) unconscious



After Wiedersheim

FIG. 124. Brain of a European rabbit. *A*, dorsal view; *B*, ventral view; *b.o.*, olfactory lobe; *cb'*, median, and *cb''*, lateral lobe of cerebellum; *cr*, crura cerebri; *ep*, epiphysis; *f.p.*, longitudinal fissure; *f.b.*, cerebral hemisphere; *hp.*, hypophysis or pituitary body; *m.b.*, mid brain; *md.*, medulla oblongata; *pv.*, pons Varolii; i–xii, cranial nerves.

activities; (*b*) conscious activities not or little controlled by the brain; (*c*) conscious activities under full mental control. The proportions of these can be roughly estimated from a study of the nervous system.

The blood

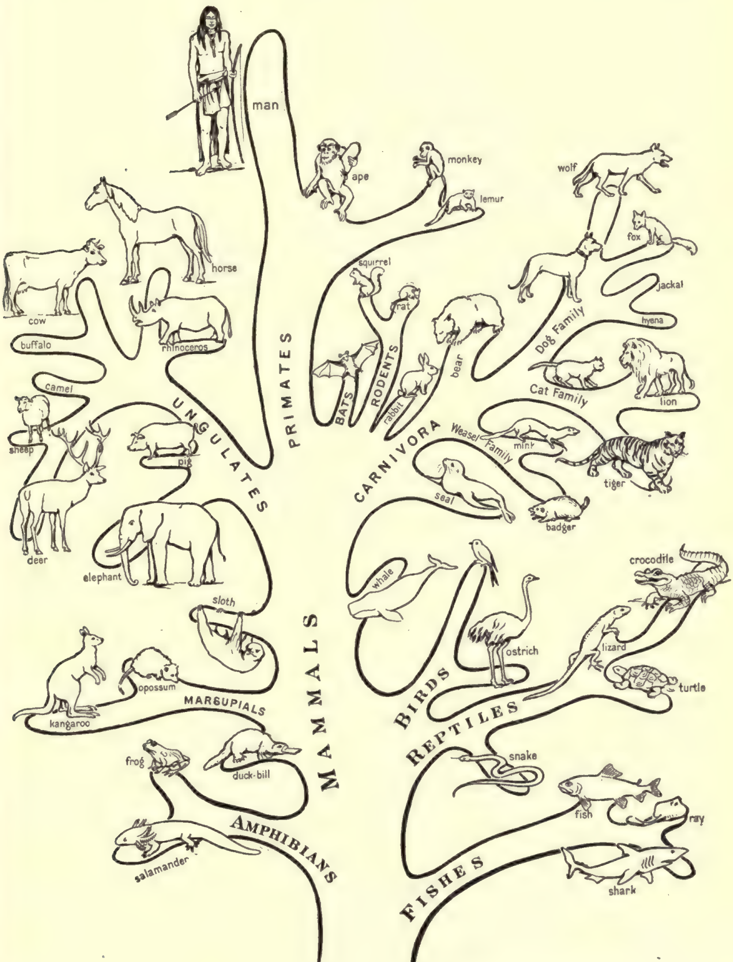
The *blood system* is not peculiar to vertebrates. Blood is a fluid containing free cells or *corpuscles*, which are of two sorts. The more numerous are rigid and disklike, and contain *hæmoglobin*, which gives the red color to the blood. These red corpuscles (which are really pale yellow when seen singly) are usually elliptical, but in mammals (except the camel family) they are circular; in mammals, also, they are without the nuclei

which nearly all cells possess. It has been estimated that there are about five millions of these corpuscles in a cubic millimeter of human blood, but the number differs according to environmental conditions, e.g., altitude. The less numerous corpuscles are colorless (so-called white corpuscles) and are amœboid, resembling minute protozoa, and like them capable of independent life and movement, given a suitable environment. The functions of these two types of corpuscles are entirely different; the red carry oxygen through the body, while the white serve as policemen, attacking and destroying bacteria and dead tissues.

The circulatory system

9. The blood is contained in a closed system of vessels known as arteries, capillaries, and veins, and is propelled through them by the beating of the *heart.* Just as the stomach is an enlargement of the alimentary canal, so the heart is primitively a mere swelling of a blood vessel, provided with muscular walls. It is so far independent of the main nervous system that its contractions will continue when it is isolated from the body. In fishes we find that the blood coming from the various parts of the body is collected in a *sinus venosus*, which has contractile walls. Thence we pass to the *auricle* or first part of the heart proper, then to the *ventricle.* In sharks and some other forms there is in addition a bulb (*conus arteriosus*) with muscular contractile walls at the beginning of the great blood vessel (the *aorta*) leaving the ventricle. In the course of evolution the sinus venosus and conus arteriosus lost their distinct character and function, while the heart became divided longitudinally, so that there were two auricles and two ventricles. Now the blood received from the great vein or veins enters the right auricle and, passing into the right ventricle, is pumped into the lungs, from which it re-

turns to the left auricle, and leaves the heart finally from the corresponding ventricle. The partition be-



From Ritchie's "Human Physiology"

FIG. 125. The "tree of life," indicating the main outlines of the evolution of the vertebrates.

tween the auricles in man is not completed until a late stage of development, and sometimes the opening, called the *foramen ovale*, does not close at all. In such cases part of the venous blood passes to the left side of the heart without going through the lungs, and consequently the blood fails to receive enough oxygen and the complexion is bluish. Fortunately such failures to complete development are very rare.

All warm-blooded animals have two auricles and two ventricles. The division of the auricles begins earlier, in the amphibians; while the crocodiles, among reptiles, have two ventricles.

Stages of vertebrate evolution

10. The principal stages in the evolution of the vertebrates may be summed up as follows:

a. Development of brain and cartilaginous skull, with paired eyes. (Cyclostomes.)

b. Development of cartilaginous skeleton, with well-formed vertebræ, pectoral and pelvic arches, and paired fins; also paired nostrils. (Elasmobranchs, sharks and rays.)

c. Development of bony skeleton and scales, also air bladder. (Bony fishes.)

d. Development of limbs for terrestrial locomotion, with five (or fewer) digits; development of lungs in adult stage, for breathing air. (Amphibians.)

e. Development of eggs with hard shells, which could be laid on land; elimination of early aquatic stages. (Reptiles.)

f. Warm blood, developed independently in birds and mammals. This necessitated a body covering of hair or feathers, or (as in the porpoise) a thick layer of fat beneath the skin. There was also developed a heat-regulating mechanism, involving the blood system and sweat glands with suitable nerve control.

g. Anterior limbs become wings; surface covered with feathers; teeth lost in modern forms. (Birds.) From these nothing further arises.

h. Covering of hair; in higher forms young nourished in body of parent. (Mammals.)

i. Upright posture, with freedom of anterior feet as hands to make tools; corresponding development of the brain to guide the work. (Man.)

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CHAPTER FORTY-FIVE

FISHES

Definition of a fish

1. FISHES may be briefly defined as aquatic vertebrates in which the skull is well developed, with jaws, and the pectoral and pelvic girdles are developed, each usually supporting a pair of fins. Respiration is by means of gills. Fishes exist in the sea and in fresh waters throughout the world. Although the remoter ancestors of fishes were undoubtedly marine, there is some reason for thinking that the actual evolution of the first fishes was in fresh water. Even sharks, now characteristically marine, appear to have formerly lived in fresh water — as shown, for example, by their occurrence in the nodules of Pennsylvanian age at Mazon Creek, Illinois. These were primitive types, little resembling the modern sharks in the details of their structure; but there is a typical shark existing today in the fresh water of Lake Nicaragua, Central America.

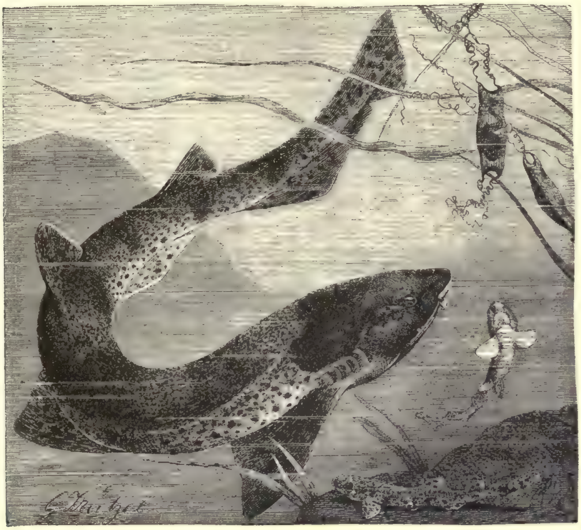
Classification of fishes

2. The classification of fishes has given rise to many differences of opinion, and is still subject to modification. The object sought is to arrange all the fishes in accordance with their natural relationships, assuming them to have evolved from a common ancestor. While there must be a true or ideal classification, accurately representing the historical facts, it is hardly to be expected that we shall ever completely attain it, though we continually move toward it. Regarding the fishes (*Pisces*) as a class, we have the following principal divisions:

Sharks and rays

(*a*) Subclass *Elasmobranchii*, or the sharks and their relatives. Some would separate these as a class distinct from the Pisces. In the true sharks and rays (or skates) — the latter being broad,

flattened-out sharks — the slitlike gill openings are five to seven on each side, the skeleton is



From "Animate Creation

FIG. 126. A dogfish, a small species of shark, with two of its young and two of its egg cases.

cartilaginous, and the skin is beset with thorn-like (placoid) scales, or granules, but in Mustelus, the dog shark, with pointed, overlapping scales. The eggs are large and comparatively few; they are deposited in leatherlike cases or hatched within the body. The teeth of sharks are characteristic — usually pointed or more or less serrated, often triangular, and sometimes very large. They are extremely hard, and consequently are often preserved in the rocks as fossils. Associated with the elasmobranchs, but very peculiar, are the *Holocephali* or Chimæras, which are comparatively rare today, but

Placoid scales

Teeth of sharks

were once more numerous, and are known to be of immense antiquity. The body is long and tapering, and the thick head, with its blunt snout and large eyes, has a most grotesque appearance. The skull is very peculiar, and the vertebral column is imperfectly developed. In the mouth are bony grinding plates instead of teeth, and it is through the fossilization of these that we know a good deal about the former abundance of the group.

Lungfishes

(*b*) Subclass *Dipneusti*, or lungfishes. The skeleton, though mainly cartilaginous, shows some tendency toward ossification. There are many anatomical peculiarities, but the most remarkable is that of the modification of the air bladder into a sac with numerous cellular spaces, which functions as a lung. Very young individuals have long, featherlike external gills. The body is covered with scales, which superficially resemble those of the higher fishes, though differing in the details of structure. It is an extraordinary thing that the scales of *Sagenodus*, preserved in nodules about fifteen million years old at Mazon Creek, Illinois, agree in almost every detail with those of *Neoceratodus*, living today in the rivers of Queensland.

From Dean's "Notes on Australian Lungfish"

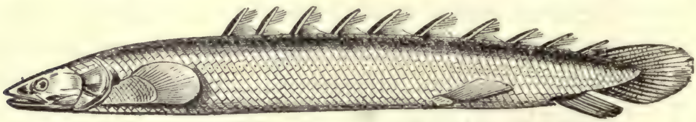
FIG. 127. The Australian lungfish, *Neoceratodus forsteri*.

The living lungfishes are the Australian *Neoceratodus* or barramunda, the *Lepidosiren* of South America, and the *Protopterus* of Africa.

(*c*) Subclass *Teleostomi*, or true fishes. Some include the lungfishes with these; others separate out additional subclasses for certain ancient types surviving in few species, including in one the curious African genus *Polypterus*, in another the sturgeon and the paddlefish. It is difficult to define the Teleostomi, as they are so numerous and diverse, but the skeleton is at least partly bony; there is only a single gill opening on each side, leading to gill arches on which are gill filaments; and there is a swim bladder, which may disappear with age. In the higher forms, with wholly bony skeleton and stiff fin rays, the pelvic girdle approaches the pectoral one, so that the pelvic fins may be directly below the pectorals. Thus it is possible to arrange the multitudes of fishes in groups representing different degrees of specialization, and it is not necessary to know much about the subject to perceive that a perch stands higher in the series (i.e., is more remote from the common ancestor) than a herring. It is also evident that the land vertebrates (amphibians) could not have arisen from the higher fishes: first because of the position of the fins in the latter, and secondly because the structure corresponding to the lungs in these fishes has been modified into the swim bladder. **The Teleostomi, or true fishes**

3. Agassiz recognized a large group of fishes, nearly all extinct, which he called *Ganoids*. The name is derived from *ganos*, brightness (Greek), in allusion to the **Ganoid fishes**

shining, smooth plates covering the body. A typical example is found in the living African genus *Polypterus*,

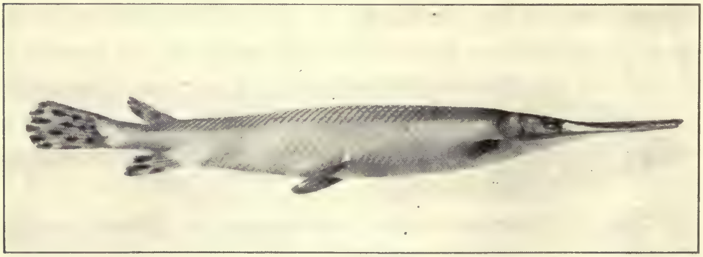


From Perrier's "Traité de Zoologie"

FIG. 128. *Polypterus bichir*. River Nile.

twelve species of which inhabit the rivers of that continent. The surface of these fishes is hard and porcelainlike, and is composed of scales of which the exposed portions are diamond-shaped. On removing these scales from the body, it is seen that each has a peg, which fits into a socket in the scale next to it.

We now know that the group of ganoids is artificial; that is to say, it associates together fishes which are not nearly related, and keeps apart those which should be more nearly associated. The *Polypterus* is a very old type, a member of a large and once dominant group called *Crossopterygii*, showing certain resemblances to the lungfishes and the primitive amphibians. Another sort of ganoid fish is the garpike of the Mississippi Valley. This is entirely different from the *Polypterus* in many important characters, and falls in a very distinct group, but it has the characteristic rhomboidal ganoid



Photograph from Am. Mus. Natural History

FIG. 129. Garpike.

Photograph from Am. Mus. Natural History

FIG. 130. Group showing nesting habits of the bowfin.

scales, though without the well-defined peg-and-socket arrangement. It is to this type that the term "ganoid" has been more especially restricted in recent years.

The bowfin (*Amia calva*), also of the Mississippi Valley, is actually nearer to the garpike than the latter is to *Polypterus*, though its scales are not ganoid. It is, however, a very distinct and isolated type, and although the scales superficially resemble those of many of the higher fishes, the fine fibrillæ or threads composing the basal part run lengthwise as they do in the lung-fishes.

Sturgeons

The sturgeons (*Chondrostei*) constitute another isolated type surviving from ancient times. They have large, bony plates on the body, and the tail is *heterocercal* — that is to say, bends upward at the end, carrying the fin on the lower side. This is a feature also observed in the sharks, and less conspicuously in the bowfin and garpike. It will be noted that these groups of archaic fishes exist in fresh water, in the large river systems of continental areas, but not in the sea.

Photograph from Am. Mus. Natural History

FIG. 131. Shovel-nosed sturgeon.

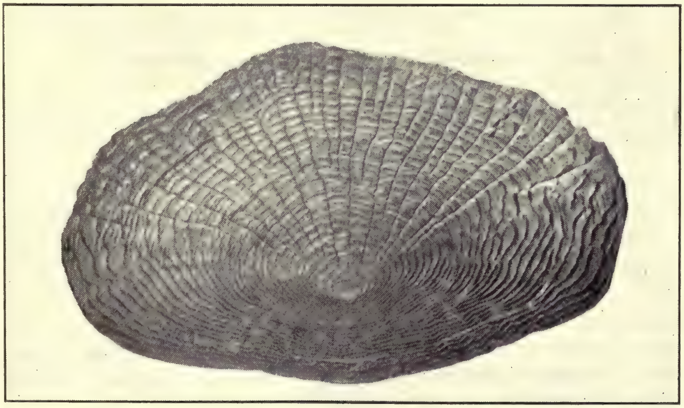
The bony fishes

4. Coming now to the typical bony fishes, or Teleostei, we find a bewildering array of families, genera, and species, both in fresh water and in the sea. Although certain fishes, such as the salmon, live in both fresh and salt water, the marine fishes are in general quite different from those of rivers and lakes. The great development of the modern families seems to have taken place at the end of the Mesozoic time, when the sea invaded large parts of the northern continents. In those days the whole Mississippi Valley, to the very bases of the present Rocky Mountains, was a great shallow sea, warm and eminently fitted for the growth and development of diverse animals. Some of the fishes were very large, the giant *Hypsodon* (or *Portheus*) exceeding any modern species of similar type. The scales show us that the fauna was not so diversified as the modern one, and it was not until the Tertiary that a number of the higher forms came into existence. No doubt the various families originated in different areas, and it was not until much later that many of them spread over the waters of the

earth. Consequently, even if at a given time in the past all the now existing families had been evolved, not so many of them would be found in any particular region as today.

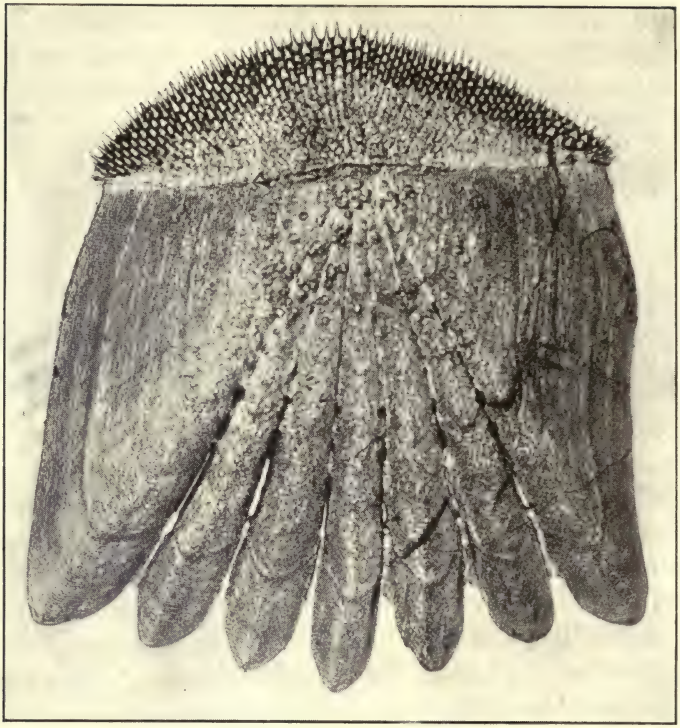
Scales of fishes

5. The scales of the bony fishes were classified by Agassiz as *cycloid* and *ctenoid*. Any scale which had a circular or oval or squarish outline, with the exposed edge even and free from teeth or spines, was called cycloid. Whenever the exposed margin showed distinct prominences resembling teeth, the scale was called ctenoid or comblike. Agassiz thought that these distinctions separated great groups of fishes, and to some extent he was correct, but it is now known that in many instances species with ctenoid scales are more nearly allied to others with cycloid, than to particular groups in which they are ctenoid. In various flatfishes, the scales are ctenoid on the upper side, cycloid on the lower side. The fact is that while the cycloid condition is undoubtedly the more primitive, it may be secondarily acquired by the loss of the ctenoid features. The case



After drawing by Max M. Ellis

FIG. 132. Cycloid scale of *Notropis cornutus*, an American freshwater fish; showing apical radii.



Photograph by J. Arthur Hutton

FIG. 133. Scale of perch, showing ctenoid margin and basal radii.

is parallel to that of the paired limbs of vertebrates; fins are more primitive than feet, yet the whale has acquired fins, although undoubtedly having an ancestor with legs. It is also easy to observe, when we come to study fish scales, that the so-called ctenoid scales are of very different types, often having little in common.[1]

[1] Scales may be prepared for study as follows: Remove them from the middle of the side of the fish, trying to avoid regenerated scales, which have the central sculpture imperfect; place them, while wet, on a glass slide, first removing the skin which covers the part which was exposed; put on a square cover glass, or if the scales are large, a second slide; use a clamp to hold down the cover glass, or two or three if a second slide has been used; put on two

Photograph by J. Arthur Hutton

FIG. 134. Cycloid scale of herring, showing transverse radii.

A further examination of ctenoid or cycloid scales shows various interesting features. The surface is marked with numerous fine lines, which are usually concentric, but in some cases transverse or longitudinal. These are the *circuli;* they are not growth rings, as some have supposed. There are, however, more or less distinct rings called *annuli*, due to irregularities of

square gummed labels, each overlapping one side of the cover glass, or if a second slide is used, the labels may bind together the ends of the slides; write the data on the labels. After a day or two the scales will be dry, and the clamps may be removed. The scales will remain in place without further attention.

growth; these have been much studied of late, because it appears that they may be used to interpret the past history of the fish. In the case of salmon, especially, the study of scales has thrown light on the life history, and has come to be of practical importance in relation to the regulation of the fishing industry. The salmon is a migratory fish, and the different surroundings affect the growth of the scales, and are recorded in the annuli. It has even been possible to infer that an extinct fish used to migrate, from a study of its scales. In addition to the marks just described, there are often radiating (occasionally transverse) lines (*radii*) representing grooves. These may extend in every direction from the nucleus of the scale, or may be all basal, or all apical; or apical and basal, but not lateral. In typical ctenoid scales, there are nearly always strong basal *radii*, and where they reach the margin the latter is often crinkled, producing a scalloped effect. Taking all these different characters together, it is often possible to classify a fish if we have no more than a single scale from the middle of the side, where the characters are best shown.

6. Some of the principal groups of bony fishes are the following:

Salmon, trout, and herrings

(*a*) *Isospondyli.* Marine and fresh-water fishes with soft fins, and the pectoral and pelvic fins far apart. The group is a large one, with very diverse families, the most important being the herrings and their relatives, and the group including the salmon and trout. The latter are especially distinguished by the second dorsal fin, a little fin above the root of the tail. Some other fishes have such a fin, but they have either very different scales, or none at all. The salmon or trout scale is cycloid, and without

Photograph from Am. Mus. Natural History

FIG. 135. Common herring (*Clupea*).

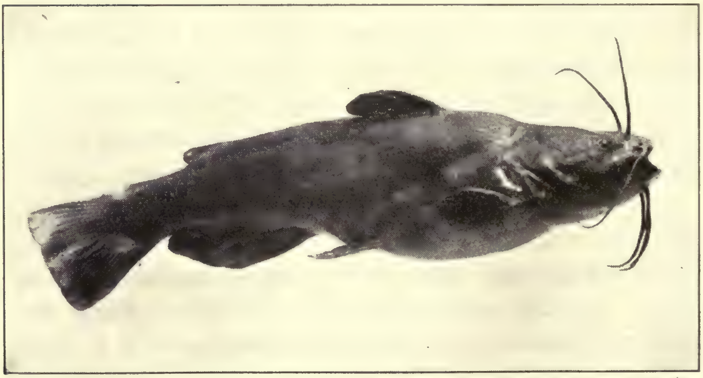
radii. In the herring group, some species have cycloid scales, others ctenoid scales; but when the scales are ctenoid, they are still very different from those of the fishes higher in the series. A remarkable feature of many of the herring family is the transverse circuli and radii of the scales, running across from side to side. These features may be seen very well in the scale of the common herring. This peculiar structure is evidently extremely ancient, as a scale from the Chico Cretaceous of California, belonging to a period fully five million years ago, is just like that of a herring of the genus *Pomolobus*.

(*b*) *Apodes* (literally "without feet," meaning without ventral or pelvic fins). The eels and their relatives, slender and mostly cylindrical fishes, are found in fresh waters and in the sea. Scales are present in some forms, absent in others, but when present are minute and of peculiar structure. The very young eel is a translucent, band-shaped creature, so different from the adult that naturalists formerly gave it a separate name. The common fresh-water eel migrates to the sea in winter, and there lays its **Eels**

eggs, which give rise to the peculiar larvæ, looking something like an Amphioxus, but with a well-formed head and large eyes.

Catfishes, suckers, and minnows

(*c*) *Ostariophysi.* A series of orders, in which the anterior vertebræ are enlarged and modified, and through them a series of small bones connects the air bladder with the ear. It seems that the air bladder thus becomes an organ of hearing. The great majority of fresh-water fishes belong to this series; only a few (certain catfishes) enter the sea. The catfishes are quite without scales, and are noteworthy for their long barbels, slender appendages in the region of the mouth. The scaly Ostariophysi common in this country are the suckers (*Catostomidæ*) and the carps and minnows (*Cyprinidæ*). The suckers may usually be recognized by the long dorsal fin and the presence of both basal and apical radii on the scales. The carp family is a very large one, with numerous small species, commonly known as "minnows" in the



Photograph from Am. Mus. Natural History

FIG. 136. Common bullhead or catfish.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 137. Carp (*Cyprinus carpio*).

streams of the eastern United States. The goldfish belongs to this family; in its wild form it is dark, the gold variety existing only in a state of domestication. The case recalls that of the canary, the wild form of which is a dull-green bird. These conspicuous and beautiful forms have arisen as variations, and have been conserved by man, who admired them. The Japanese have also obtained in a similar manner many strange and grotesque forms of goldfish, which would have no chance for success in the struggle for existence in the wild state.

Pikes and killifishes

(*d*) *Haplomi*. The pikes (*Esocidæ*) and the killifishes (*Pœciliidæ*) are common fresh-water forms. Some of the latter are excessively abundant in certain localities, and are very important as destroyers of mosquito larvæ. The pikes will be recognized by the elongate snout,

and the single dorsal fin placed far back over the base of the tail. The Pœciliidæ are relatively small, often spotted or striped, with the single dorsal fin nearly always posterior to the middle, and the caudal (tail) fin rounded or squared (truncate), not bifurcated. The scales are cycloid, with strong basal radii.

Spiny-rayed fishes

(*e*) *Acanthopterygii.* Spiny-rayed fishes; generally known by the anterior position of the pelvic fins, and the rays of some of the fins hard and spinelike. The scales are generally ctenoid, with not merely marginal teeth, but a considerable area covered with fine projections or variously modified. Such scales usually have strong basal radii, arranged in a fanlike manner, and the basal margin is likely to be scalloped. When a typical spiny-rayed fish, of which the perch or the sea bass may be taken as an example, has been thus defined, it is necessary to state that within the group as now recognized are many exceptions. There are, first of all, the relatively primitive families, such as the flying-fish group, in which the scales are wholly cycloid. These strange fishes have the pectoral fins enormously enlarged, serving as organs of temporary flight; and the lower lobe of the tail fin is elongated, so that it may be used to strike the water as the flying fish approaches its surface, and thus give it a new start. These fishes are of course specialized animals in their own way, but not in the direction of the mass of the acanthopterygians, in relation to the special characters in which they are primitive. Aside from the relatively primi-

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 138. Common sunfish (*Eupomotis gibbosus*), one of the spiny-rayed fishes.

tive members of the group, there are others which lack the special characters for opposite reasons: they are highly specialized members of groups which once possessed them, and in which they have been lost. Thus, for example, the cycloid scales on the lower side of certain flatfishes certainly represent a secondary adaptation, not a primitively cycloid character. Certain families are entirely without scales. The modifications in structure and appearance are almost endless, producing many grotesque forms. The flatfishes, adapted for life on sandy sea bottoms, have one side colored and the other, which is away from the light, colorless. The head is curiously twisted and both of the eyes are, of course, on the upper or colored side of the fish. This metamorphosis, gained through ages of evolution, is passed through in the development of each individual fish. The very young have the body symmetrical. **Flatfishes**

Reference

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CHAPTER FORTY-SIX

AMPHIBIANS

Discovery of the land by vertebrates

1. In Palæozoic times, many millions of years ago, certain vertebrates learned to live upon the land. Already the land was populated with many kinds of plants and multitudes of insects. A vertebrate, entering upon aërial existence, was necessarily subject to certain disadvantages, especially the chance of desiccation. This danger has not yet ceased to menace the lowest land vertebrates. Thus, on one occasion, it was noticed that little toads were leaving a roadside ditch in which they had lived as tadpoles, and, trying to cross the road, were perishing in great numbers in the thick dust. The transition from water to land could not be abrupt. The eggs were still laid in the water, and the young stages passed therein; but emergence on the land opened up a great new territory, with warmth and food in abundance. On land, gills were no longer suitable for breathing, and so their place was taken by internal sacs — that is to say, by lungs. The lungfishes already have such organs, so here the transition must have been gradual; indeed, it could otherwise hardly have taken place. We know least about the origin of the legs for terrestrial locomotion, with typically five digits. They are certainly modified from the paired fins of fishes, but the earliest known four-footed animals have passed beyond the transition stage.

Amphibians

2. The first land vertebrates, arising in some such manner, were amphibians. The word (from the Greek, meaning "both" and "life") has reference to the life both in water and on land, to the metamorphosis from the tadpole to the frog or toad. As a matter of fact, this metamorphosis does not always occur; many species

are permanently aquatic, while the Alpine salamander is viviparous. The surface of the body in living species is smooth or rough, and ordinarily without scales, but there is a group of legless amphibians possessing minute scales in the skin. The skull articulates with the atlas, or first vertebra, by two surfaces or condyles, whereas all living reptiles, and all birds, have only one. The mammals have two condyles, as have the amphibians. Gills are present in the early stages. The red blood corpuscles are oval, and show distinct nuclei.

Palæozoic amphibians

3. In Palæozoic times there existed amphibia, often of large size, more or less covered with a dermal armor. These animals, known as *Stegocephalia*, had various fishlike characters, some even having overlapping scales. In several different localities their footprints have been found, so that we know the outward form of the five-toed feet. In some species the anterior feet have only four toes, showing already a reduction of one from the primitive number. These Stegocephalia, though apparently well protected, died out entirely at an early period, leaving the race of amphibians to be continued by forms which, although often abundant, never reached the size of the largest of the early group. The groups now living are the following:

Legless amphibians

(*a*) *Apoda* ("without feet"); wormlike or snakelike tropical animals, without any trace of legs, and even without pectoral and pelvic girdles. They are thus much modified for their burrowing life, yet at the same time they show primitive features, the most interesting being the presence of small scales in many of the genera. These scales are imbedded in the skin, and recall those of the eels. The eyes are little developed. The animal, at least in the genus

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 139. A water newt (*Notophthalmus viridescens*).

Ichthyophis of the Oriental region, produces quite large eggs, and the embryo at a late stage has long external gills and more or less of a tail fin. At the time of hatching, the gills are lost, though the larva is aquatic.

Tailed amphibians

(*b*) *Urodela*, or tailed amphibians; generally known as salamanders, water dogs, or newts. In the American genus rather ridiculously called *Siren* by zoölogists, but "mud eel" by other persons, the body is snakelike, and only the anterior limbs are present, while the jaws are without teeth. This is a specialized or degraded form; the others have teeth in both jaws, and the legs are all present. The giant salamander of Japan has been known to reach a length of over 5 feet. A related fossil form was discovered in Germany, and was announced, when described in 1726, as "homo diluvii testis," the man who witnessed the deluge! Salamanders, when terrestrial, live in damp places, and often breathe largely through the skin. The so-called water dog of

the United States and Mexico, also known as the axolotl, is capable of reproducing while still in the aquatic condition, with external gills. It has, nevertheless, a mature, terrestrial stage, in which it appears as a salamander with large yellow spots or blotches. A remarkable newt, the *Typhlomolge*, is found in underground waters in Texas. Being permanently in the dark, it is colorless, and the eyes are hidden and useless.

(*c*) *Anura* ("without tail"), the tailless amphibians; also called *Batrachia Salientia*, from their habit of jumping. These are the frogs and toads, well known to all. The species are numerous, and differ much in details of structure. The young are known as tadpoles, and undergo a curious metamorphosis. The tail is not dropped off, but absorbed. One group of

Jumping amphibians; frogs and toads

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

Fig. 140. Tadpoles of common frog.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 141. African swimming frog.

toads, called the *Aglossa*, is without a tongue. The tongue of the frog is a remarkable structure, attached in front instead of behind, and capable of being thrust out with great rapidity to take an insect. Some toads have very poisonous secretions. Gadow calls attention to the brilliant red under surface of the fire-bellied toad of Germany, and shows that this serves as "warning coloration." He states that the secretion of the skin is very poisonous, and he knows of no creature which will eat or even harm them. He kept large numbers in a vivarium, together with various snakes, tortoises, and crocodiles; but for years they remained unmolested, although they shared a pond in which no other frog or newt could survive. Hungry water tortoises would stalk them, and touch them with the nose to get the scent,

when they would immediately withdraw. The little toads remained motionless, "well knowing that quick movements, or a show of escape, would most likely induce the tortoise to a hasty snap, with consequences to be regretted by both." The expression "well knowing" must be taken with reservations, as the action is doubtless instinctive.

We usually distinguish the frogs from the toads by the fact that the first are smooth and more generally aquatic, the second rough or warty, and in the adult stage often found far from water. This separation is satisfactory only for the most common forms. The typical frogs have teeth in the upper jaw, but none in the lower jaw, while the typical toads have no teeth in upper or lower jaw. The tree frogs or Hylidæ have more or less enlarged adhesive disks at the ends of the toes, which enable them to climb with ease and safety.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 142. Giant tree frog.

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CHAPTER FORTY-SEVEN

REPTILES

Reptiles distinguished from amphibians

1. Modern reptiles include the lizards, snakes, crocodiles, and tortoises. In the popular mind they are confused with the amphibians, but they represent a very distinct group, much more perfectly adapted to terrestrial life. Whereas the amphibians lay soft eggs in the water, and pass at least their early stages in that medium, the reptilian type is able to produce hard-shelled eggs, which are laid on land, often in the driest situations. It is the development of an egg shell which makes terrestrial life possible, and enables the animals to exist far from water. The only practicable alternative to this arrangement is viviparity; and it is interesting to see that the birds and mammals, each diverging from a primitive reptilian group, have adopted the two possible methods, — the birds continuing the egg-laying habit, and the mammals, except the most primitive, giving birth to active young. Even among the reptiles occasional species are said to be viviparous. Such, for instance, are the snakelike lizard or so-called slow-worm (*Anguis fragilis*) and the viviparous lizard (*Lacerta vivipara*), both common in England. In these cases, however, the eggs hatch without being laid or at the moment of laying, and there is no arrangement for prolonged nutrition in the body of the parent, as in the higher mammals. It is interesting to note that the marine turtles, now well adapted to sea life, come to land to lay their eggs, thus reversing the procedure of the amphibian.

Characters of Reptilia

2. Reptiles are cold-blooded, with a scaly skin; they breathe by lungs, which are much less complex than those of mammals and birds. In all living forms the skull has a single occipital condyle; that is, a single

place of articulation with the first vertebra. In this, reptiles agree with birds, and differ from amphibians and mammals. On account of this character, it used to be supposed that the mammals had arisen directly from the amphibians; but more recently fossils have been found in South Africa which are distinctly reptilian, and approach the mammals more closely than any amphibian. These ancient animals, the cynodont or dog-toothed reptiles, had paired occipital condyles and the teeth distinctly differentiated into incisors, canines, premolars, and molars. Presumably they were cold-blooded and without hair, but we have no knowledge of anything but their bones and teeth.

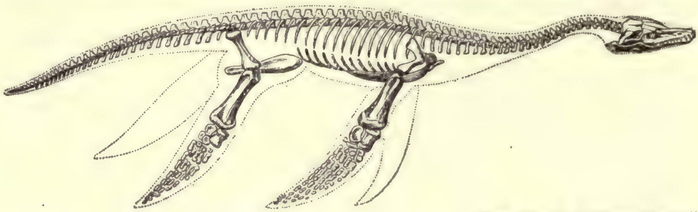
Classification of reptiles

3. The classification of living reptiles is relatively simple, because we have today only the remnants of a mighty host. Numerous and diverse as are the species of snakes, lizards, and turtles, they appear insignificant beside the dinosaurs, plesiosaurs, pterosaurs, and ichthyosaurs of several million years ago. It was in the Mesozoic age that the reptiles reached the maximum of size and diversity of structure, — a time when the mammals were small and insignificant, apparently promising little for the future. There still exists in New Zealand a remnant of the Mesozoic reptilian fauna, the tuatera of the Maoris, *Sphenodon* of the naturalists. This animal, now almost extinct, resembles a large lizard, the back ornamented with spines. The structure of the skeleton shows that it has nothing to do with the lizards, but is related to some of the most ancient fossil forms; it is a relic of antiquity which has managed to survive in an isolated part of the world, free from competition.

6. Parallel or analogous adaptations are common among animals, and thus we find that millions of years

Adaptations for swimming and flying

before there were any whales or bats, swimming and flying mammalia, the reptiles had developed similar



From Zittel's "Palæontologie"

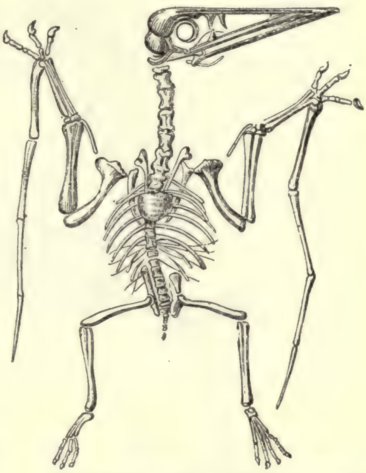
FIG. 143. Skeleton and body outline of a plesiosaur, restored by R. Owen. Jurassic of Dorsetshire, England.

types. The plesiosaurs were aquatic and had long paddles for swimming, in place of legs. As with the whales, the bony framework of these structures shows plainly that they are derived from legs, and not directly from fishlike fins. The pterosaurs, on the other hand, had long wings and were capable of flight; yet they were entirely different from birds or bats. One of these creatures, found fossil in Kansas, had a spread of wings measuring nearly 20 feet. It must have been curiously like an airplane. In spite of their wonderful adaptive features, all these animals died out; indeed, we may say that they disappeared *because* of their adaptive features, — they were specialized for particular modes of life, and when conditions changed, they could not change to meet them.

Giant reptiles of the Mesozoic age

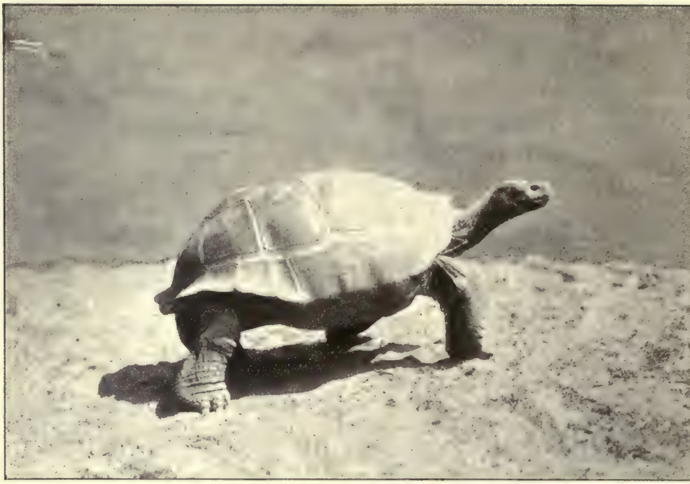
5. The dinosaurs (the name means "terrible reptiles") were the gigantic reptiles of the Mesozoic; they flourished for about nine million years, and then became extinct. The disappearance of these great, stupid beasts coincides approximately with the rise of the more modern type of mammals, warm-blooded, active, and relatively large-brained. Many dinosaurs were herbivorous, feeding on vegetation, and some of these were

the largest of all four-footed animals. The long tail at one end is so like the long neck at the other, with its quite insignificant head, that we have to look twice at the skeleton of the *Diplodocus* to be sure which is which. The problem of feeding these vast creatures must have been a difficult one, and they possibly died out for lack of sufficient food, or it may have been because of disease or predatory enemies. Possibly the mammals took to eating their eggs or young. Even in their prime, these great animals had terrible enemies in other dinosaurs, which were carnivorous. This we know from their sharp and powerful teeth, adapted for holding and tearing flesh. These carnivorous dinosaurs had the front legs adapted for grasping or tearing, but not for walking. They walked on their hind legs, which were mostly three-toed and resembled more or less those of birds. Consequently, when their tracks were discovered many years ago by geologists ("footprints in the sands of time"), they were supposed to be those of gigantic extinct birds. The armored dinosaurs were grotesque creatures, with massive bony armor plates, and crests or spines covering parts of the body and tail. They were herbivorous, and were presumably protected by their armor from the attacks of the carnivorous forms. Other dinosaurs had extraordinary horns, recalling the rhinoceros.



Zittel's "Palæontologie" (after H. v. Meyer)

FIG. 144. Skeleton of a pterodactyl; a flying reptile, one of the Pterosauria.



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 145. Giant land tortoise (*Testudo vicina*) from the Galapagos Islands. Similar large tortoises formerly inhabited continental areas, but they have died out, leaving only a few species on islands.

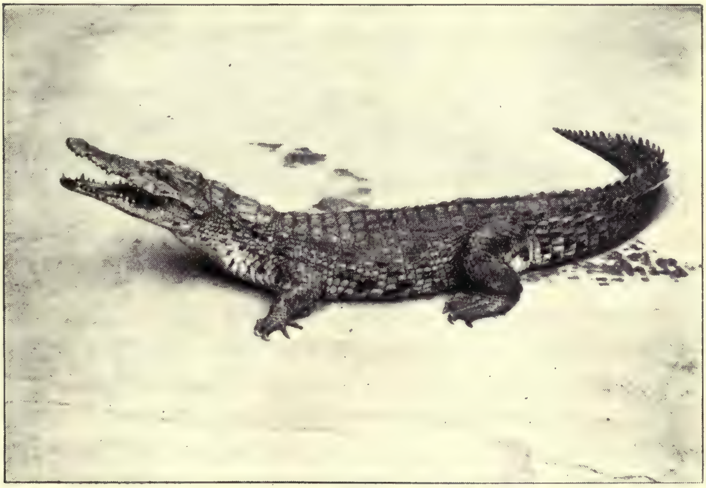
Tortoises and turtles

6. The tortoises or turtles (*Chelonia*) are easily recognized by the bony covering of the body and the toothless jaws. The covering or shell consists of a dorsal or upper portion, called the *carapace*, and a ventral or lower *plastron*. In very young animals the shell is soft, the plates not being fully ossified. The surface is covered with horny shields, which according to Gadow are phylogenetically older than the underlying bony plates, and do not correspond with them either in number or position. These shields furnish the well-known tortoise shell, which is obtained from the hawksbill turtle (*Chelone imbricata*) of tropical seas. In certain river turtles the shell is covered with soft, leathery skin instead of hard shields; the soft-shelled turtle of the United States is an example. In the leathery turtle (*Sphargis*) the limbs are transformed into paddles, and

the same is true of the very different *Chelone*. These are independent adaptations to marine life, recalling the whales and the plesiosaurs. Gigantic land tortoises exist in the Galapagos Island and the islands of the Indian Ocean, where they have been able to survive on account of their isolation. In former geological times similar great tortoises were found on continental areas, — for example, in Colorado and in Egypt.

Crocodiles and alligators

7. The *Crocodilia*, or crocodiles and alligators, were formerly much more numerous than at present. They superficially resemble gigantic lizards, but are structurally quite distinct. There are several living genera, of which the most familiar are *Crocodilus*, the true crocodiles, and *Alligator*, the alligator. The latter is distinguished from the former by the broad, rounded snout. The alligator of the southern United States may be looked upon as a remnant of an old fauna, since animals of this genus were formerly much more



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 146. Senegal crocodile.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 147. American alligator (*Alligator mississippiensis*).

widespread, occurring in Europe and Asia. It used to be supposed that there were no living Old World alligators, but in 1879 a species was described from China. The species of living crocodiles are relatively numerous, and are known on both sides of the world.

Lizards

8. The lizards, or *Lacertilia*, are extremely numerous and widely distributed over the earth. The ordinary forms are scaly, and possess four well-developed legs, but there are strangely modified lizards without legs and even without distinct scales. In such cases the structure of the skull serves to indicate that they are of the lizard group, and not the snakes they seem to be. The snakelike form has been developed independently among the fishes (eels), lizards, and true snakes. The Gila (pronounced *hee'la*) monster (*Heloderma*) of Arizona is a poisonous lizard, and appears to possess "warning coloration," dark brown and orange. The chameleons are African arboreal lizards, famous for their power of changing color. This is done through the movements

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 148. Gila monster (*Heloderma suspectum*).

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 149. Iguana (*Iguana tuberculata*), a large lizard common in tropical America.

of the pigment in the chromatophores; it may be brought near the surface, giving a dark color, or withdrawn from sight, when the skin appears pale or white. Chameleons have enormously long tongues, which are thrust out to capture insects. Lizards have considerable power of renewing lost parts, particularly the tail. A species found in New Mexico has a bright blue tail, and it can hardly be doubted that this serves to attract

a pursuing enemy, which seizes the brilliant object, while the lizard escapes, to grow a new tail in due time.

Snakes 9. The snakes, called *Ophidia*, are well known to all and easily recognized, unless the comparatively rare legless lizards and amphibians are confused with them. They are highly specialized animals, in which the limbs and limb girdles have disappeared. The eyes are without eyelids, which are present in the lizards. Many snakes are poisonous, but more are harmless, and the latter should be protected as useful animals, since they destroy many mice and gophers. The poisonous rattlesnakes, instead of having warning coloration, possess a rattle on the tail, by means of which they are enabled to frighten possible enemies.

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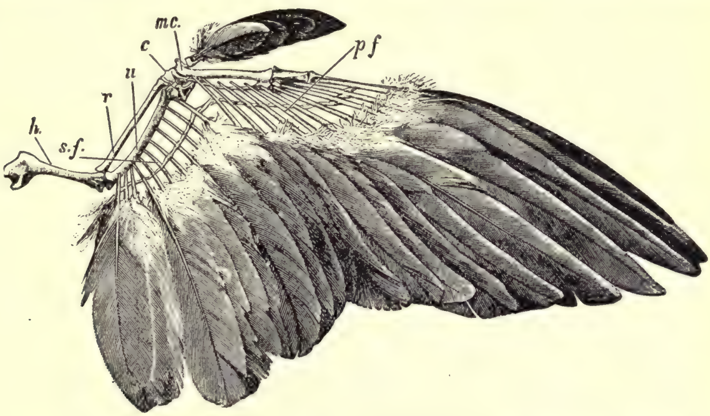
CHAPTER FORTY-EIGHT

BIRDS

Characters of birds

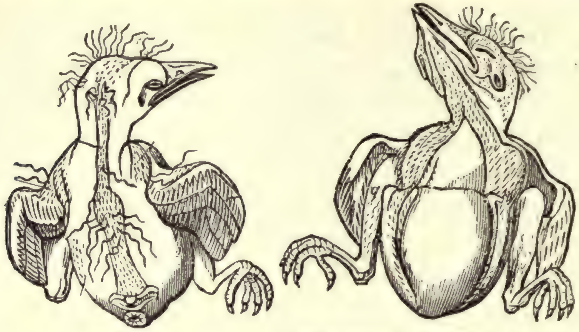
1. All birds have feathers, and in this they differ from every other group of animals. In common with the reptiles, they lay hard-shelled eggs and have scaly feet, but they resemble mammals in having warm blood. The blood is, indeed, warmer than that of mammals; in the small, active, singing birds it is at least 10 degrees (Fahrenheit) above that of man. In all zoölogical arrangements the birds (*Aves*, from the Latin *avis*, a bird) follow the reptiles and are followed by the mammals; but no zoölogist believes this to have been the course of evolution. The mammals and birds arose independently from reptilian ancestors, and today the birds are much more reptilian than mammalian in structure. The feathers must be regarded as greatly modified scales, and the single occipital condyle at the base of the skull is a reptilian feature. Although



From Thompson's "Zoölogy"

FIG. 150. Wing of a dove, showing the bones and important feathers: *h*, humerus; *r*, radius; *u*, ulna; *c*, carpals; *m.c.*, carpo-metacarpals; *s.f.*, secondary feathers; *p.f.*, primary feathers.

modern birds are without teeth, very ancient fossil forms are known in which the jaws have numerous



From Owens' "Comparative Anatomy"

FIG. 151. Young blackbirds, showing the developing feather tracts.

sharp teeth like those of a reptile. The wings are of course modified anterior limbs, as may be seen by comparing the bones with those of other animals. Thus the beautiful idealistic paintings of angels, in which these beings are represented with human arms and hands, and in addition birdlike wings, are contrary to the teachings of anatomy. The anatomist prefers the winged sandals of Mercury, which do not offend against his science.

Feathers

2. Feathers are not scattered over the bird at random. Mr. C. W. Beebe figures the sprouting feathers of a 12-day embryo chick, and it can be seen that they are arranged in rows crossing each other X-wise, just as the scales of a fish. In the penguins, probably the most primitive of living birds, the feathers grow on all parts of the body, but in other birds they occupy definite areas. These feather tracts can be observed when the bird is plucked and the points of attachment become visible; since they differ in the various groups of birds, they are of assistance in classification. Although the

feathers are thus attached to definite regions of the body, they ordinarily cover the surface, and of course prevent undue loss of heat. It is evident that the warm-blooded type of organization developed along with the hair or feathers which helped to conserve the heat and protect the body from rapid changes of temperature. In the case of those mammals which have lost the hairy covering, special arrangements attaining the same end are found, — thick layers of fat in whales and porpoises, clothes and houses for man. No birds are as naked as man, but some have large bare areas. The turkey vulture, for example, has the head and neck bare, because its habit of feeding upon carrion would make it impossible to keep feathers in that region decent. The colored bare areas about the heads of various birds appear to serve for ornament.

Structure and colors of feathers

3. A typical large feather, used in flight, consists of a main shaft, from which arises on each side an oblique series of barbs. These *barbs* can be seen under the microscope to be compound, giving rise on each side to a series of *barbules*. Thus the structure resembles that of a bipinnate leaf. The barbules, however, are provided with little hooks, the *barbicels*, which hold on to the barbules of the adjacent barbs and thus keep the surface of the feather intact, enabling it to resist the pressure of the air. On closer examination, it is seen that not only do the various feathers on a single bird differ in structure, but different kinds of birds have different feathers. If we knew nothing of birds but their feathers, it would be possible to construct a fairly accurate classification. The colors of feathers, like those of the scales of butterflies, are due partly to pigment and partly to structure. Pigment is coloring matter which may be extracted, corresponding to a dye.

Blacks, reds, browns, and usually yellows are due to such pigments. The bluebirds, however, furnish no more blue on analysis than the rainbow; the pigment present is not blue at all, and the brilliant effect is due to the manner in which the surface of the feathers reflects the light. This can be determined by examining the feathers by transmitted light under the microscope. In all such cases the underlying pigment is connected with the effect produced, but the manner in which the light is reflected is the more important factor.

Moulting

4. A caterpillar, as it grows, sheds its skin from time to time; a snake does the same. The scales of fishes and reptiles, and the feathers of birds, are renewed when lost. In birds, however, we find a periodical loss of feathers, the *moult.* Feathers, like clothes, wear out, and were they not renewed the bird would become "a thing of rags and patches." Moulting renews the plumage, replacing the old clothes by new and clean ones. Usually the moult is annual, after the rearing of the young; but it may occur more frequently. The feathers do not all come out at once, or the bird would be disabled. Some water birds, as ducks, do indeed shed their primary or large wing feathers at once, and for a while are unable to fly. If the external physical conditions, such as the amount of moisture, are greatly altered, the color of the feathers after a moult may be modified. In the ptarmigan, however, the plumage regularly changes to white in the winter, to harmonize with the snow, on which the bird is almost invisible. This is not due to a change in the feathers themselves, but to an alternation of white and brown colors in successive plumages. Once a feather is formed, it is a dead structure, like a hair, and cannot be modified, except through wear or dirt affecting its appearance.

In some cases, however, the effect of wear is quite marked. Thus Beebe points out that in the cock sparrow the throat feathers have dusky-brown tips, and as these wear away in the spring the clear black centers appear. Thus the worn sparrow is more handsomely marked than the one which has recently moulted. A very extraordinary case is that of the tropical American motmot (*Momotus*), which has long tail feathers, the ends racket-shaped, with the shafts bare for a considerable distance before the broad tips. It is found that the birds themselves remove the barbs for a considerable distance, and thus produce this singular effect. Are we obliged to suppose that these birds, like some human beings, regularly mutilate themselves for the sake of fashion? It seems to be the case that for a certain distance the barbs are loosely attached, and hence fall away as the bird preens the tail feathers. Thus it is possible that a structural peculiarity and an instinct combine to produce the result, without any deliberate intention on the part of the bird.

Anatomy of birds

5. The bird's bones are peculiar, yet they agree in general type with those of other vertebrates. The lungs are supplemented by a series of air cavities, and even many of the bones in the majority of birds contain air. In the ostriches and penguins, which do not fly, there are no air spaces in the bones, but their presence is not invariable in flying birds. The terns and swifts, remarkable for their powers of flight, have solid bones. The *sternum* or breastbone in flying birds is keeled, presenting a more or less narrow edge extending outward, as every one who has carved a chicken knows. This keel affords attachment to the great pectoral muscles, which are used in flight. The early experiments in aviation, in which men attached winglike

structures to their arms, were doomed to failure, because we have not a keeled sternum. We have the pectoral muscles, but the greatest athlete could never develop them as the bird does, having no proper surface for attachment. Relatively to the size of the bird, the keel is largest in those which use the wings most actively. Thus the humming bird, which is incessantly in motion, hovering over the flowers, has a proportionately immense sternum when compared with the soaring albatross. It is said that the wings of a humming bird execute from six hundred to a thousand strokes a minute. In groups of birds which have lost the power of flight the keel of the sternum also has gone; such are the ostrich, cassowary, and apteryx. It was once thought that all such birds were primitive, belonging to a type prior to the evolution of flying structures; but this view is contradicted by other anatomical evidence.

Senses of birds

6. Dogs and ants are remarkable for their keen sense of smell. The horse, with expanded nostrils, sniffs the breeze. Birds have very little sense of smell, and depend upon their sight. The vulture does not detect the odor of carrion; it may be close at hand, and offensive to the human nostril, but the bird perceives nothing. Yet from the sky he detects the fallen animal by its position and lack of motion. Sight suffices where the most acute nostrils would fail, owing to the distance. The bird's eyes are not only large, but capable of a remarkable amount of *accommodation;* that is, adjustment to near or far sight. It is almost as though the soaring eagle possessed a telescope, which could be immediately converted into a microscope as it swooped upon its prey. The human eye is incapable of such feats, though possessing the same powers to a limited extent; that we see smaller and more distant things than

any bird sees is due to our invention of instruments, supplementing by lenses the imperfections of our eyes. In addition to the peculiarities of the eye itself, birds have a sort of extra eyelid, the *nictitating membrane*, which when drawn across the eye shades it from intense light. This structure is present, more or less developed, in many other vertebrates.

Primitive birds with teeth

7. In any classification of birds, the *Archæopteryx* stands quite apart. Although extinct many millions of years ago, it is known by two wonderfully preserved fossils, from the Upper Jurassic rocks of Solenhofen in Bavaria. Not only are the forms of the bones clearly indicated, but the impression of the feathers on the rock remains. The creature is described as of about the size of a crow, with a small head having toothed jaws and no true beak. The neck vertebræ were less numerous than in modern birds. The tail was most remarkable, with about twenty bones as in a reptile, but covered with long feathers. There were birdlike wings, with long feathers adapted for flight, but these wings had in addition three digits, each with a hooked claw. The legs were four-toed. This animal was certainly a member of the class Aves, since it had feathers; but in other respects it was intermediate between birds and reptiles. It is almost the ideal "link" which evolutionists might have postulated and hoped to find. Other toothed birds, called *Hesperornis* and *Ichthyornis*, have been found in the Cretaceous rocks of Kansas. These are not only more recent than the *Archæopteryx*, but are much more like typical birds.

The great fossil bird of Wyoming

8. Many other extinct birds are known, though the remains are mostly fragmentary. From the Lower Eocene of Wyoming comes the gigantic *Diatryma*,

Drawing by Edward W. Berry. Used by courtesy of artist and "Scientific Monthly"

FIG. 152. Restoration of the Archæopteryx, a Mesozoic toothed bird.

nearly 7 feet high, with a large head and short and massive neck. The beak is extremely large and compressed, and quite without teeth. The wings were greatly reduced, as in the cassowary, and the bird was wholly unable to fly. Although fragments of *Diatryma* were discovered in New Mexico in 1874, no one had any accurate idea of the nature of the bird until Mr. W. Stein found a nearly complete skeleton in Wyoming in 1916.

Birds of the asphalt beds

Passing over about three million years, we come to the deposits of the Rancho La Brea, near Los Angeles, California. Here a great number of bones of mammals and birds are found embedded in asphalt, which belongs to the Pleistocene period, and is thousands but not millions of years old. The very numerous birds, which were entrapped by the tar which still comes to the surface in the locality, have not yet been fully described. Their structure was, however, essentially like that of living species, the modernized type of bird having fully evolved at the time represented by the deposits.

9. Coming now to the living birds, we can notice only some of the principal groups, regarded as Orders.

Penguins

(*a*) *Sphenisciformes.* Penguins, a group of marine birds, confined to the antarctic regions, extending as far north as Australia and the southern end of South America. They are quite incapable of flight, the wings being reduced to flappers which are used in swimming. These strange birds abound on the coasts of the antarctic continent. Here the Emperor Penguin, a large and handsome species, nests at the coldest season of the year, in darkness, with the temperature 25 to 75 degrees below zero.

Photograph from Am. Mus. Natural History

FIG. 153. King penguin group.

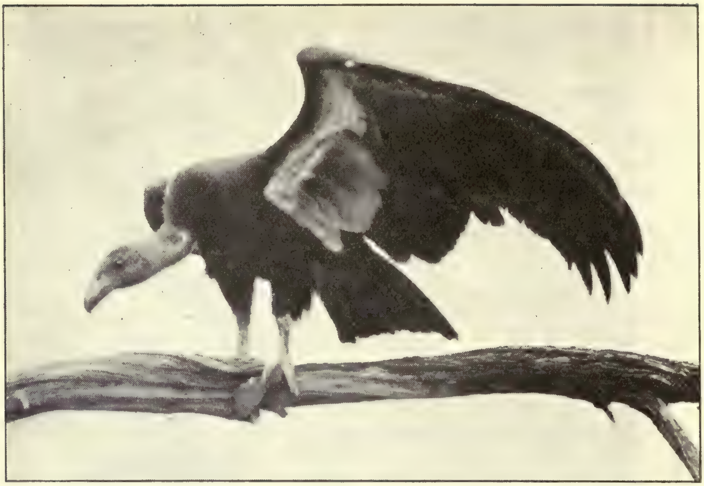
(*b*) *Struthioniformes*. Ostriches, the largest of existing birds, though not so large as the *Dinornis maximus* or moa of New Zealand, which became extinct since man inhabited that country. The ostrich, of which there are several distinct races or species, inhabits the drier parts of Africa and Arabia, but was formerly more widely distributed in Asia. As every one knows, the wings are unsuited for flight, while the legs are long and powerful, enabling the birds to run at a speed of 60 miles an hour, though this cannot be maintained for long. On account of the valuable plumes, ostriches are domesticated, not only in Africa, but also in Arizona and California. **Ostriches**

From Zittel's "Palæontologie"

FIG. 154. A moa (*Dinornis*), restored, and three kiwis.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 155. Emeu and young.



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 156. California condor (*Gymnogyps californianus*), the largest of North American vultures, now extremely rare.

Cassowaries

(*c*) *Casuariiformes.* Cassowaries and emeus. The emeus are Australian, while the cassowaries inhabit New Guinea and the adjacent islands. The wings are quite rudimentary, and there are no ornamental wing and tail plumes such as are seen in the ostrich. The cassowaries have a long crest or helmet on the head, and the bare skin of the neck and head are brightly colored.

South American ostriches

(*d*) *Rheiformes.* The rheas or South American ostriches; differing from true ostriches by the presence of three toes (ostriches having only two), a feathered neck, practically no tail, and other characters. Three species are known; one of them, *Rhea darwinii*, was discovered by Darwin when he made his journey around the world.

(*e*) *Apterygiformes*. The *Apteryx* or kiwi of New Zealand; a genus of birds about the size of a fowl, with long, slender beak and entirely rudimentary wings. They are somewhat related to the emeus on the one hand, and the extinct moas on the other, but constitute a very distinct and isolated group, surviving in New Zealand because of the absence of carnivorous mammals and other enemies. Five forms are recognized. **The kiwi of New Zealand**

(*f*) *Colymbiformes*. Loons and grebes. Here we first come to a North American group, well represented in the northern hemisphere. They are aquatic birds, with webbed or lobed toes, and capable of vigorous flight. **Loons and grebes**

(*g*) *Procellariiformes*. Albatrosses and petrels, marine birds with tubular external nostrils. They are quite distinct from the gulls, with which they are often associated and which they more or less resemble. They are to be found in mid-ocean, and nest on isolated rocky islets, where they are usually free from molestation. **Petrels and their relatives**

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 157. Black-necked stork, or jabiru (*Xenorhynchus asiaticus*), found from India to Australia.

(*h*) *Ciconiiformes*. Storklike birds, a miscellaneous assemblage including storks, ibises, herons, cormorants, pelicans,

Storks and their relatives

gannets, flamingos, and others. The order contains very divergent elements, and should perhaps be divided. They are wading or swimming birds, and are best recognized by the peculiar features of the several genera. They are associated together on anatomical grounds, and on the same grounds kept entirely apart from the cranes and some other birds with which they might be confused. The birds afford many examples of convergent evolution, in which different groups have produced species adapted to the same general mode of life, and consequently superficially more or less similar.

Ducks, geese, and swans

(*i*) *Anseriformes.* Ducks, geese, and swans, familiar to all. They are most easily recognized by the form of the bill. The young are covered with down, and are able to swim soon after hatching from the egg. Nearly all have webbed feet.

Birds of prey

(*j*) *Falconiformes.* Also called *Raptores*, or birds of prey; including the hawks, eagles, vultures, and their relatives. The hooked bill is characteristic, though it is found in other birds, such as the owls and parrots. The owls, though resembling the hawks in their flesh-eating habits and the form of the bill, are really not related to them; in fact, modern students of birds associate the owls more closely with the humming birds than with the Falconiformes. The national bird of the United States is the so-called Bald Eagle, *Haliætus leucocephalus*, — the specific name meaning "white-headed" in Greek. It is widely distributed over our country, but by no means peculiar to it.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 158. Mute swans (*Olor olor*); an Old World bird, domesticated for about seven centuries.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 159. Canada geese (*Branta canadensis*).

Fowls and their relatives

(*k*) *Galliformes*. The fowls and their relatives. The word "fowl" comes from the same root as the German *vogel*, and originally meant simply a "bird." Words, like the birds themselves, become specialized. In addition to a number of peculiarities in the skeleton, the fowls are characterized by the large crop. The family *Phasianidæ* (pheasant family) includes the turkey, guinea fowl, grouse, ptarmigan, quail, prairie chicken, partridge, and many kinds of pheasants. It further includes the genus *Gallus*, which contains the domestic fowl, originally a native of the Oriental region. Here also comes the peacock (*Pavo*), likewise a native of Asia.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 160. Harpy eagle (*Thrasaëtus harpyia*); tropical America.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

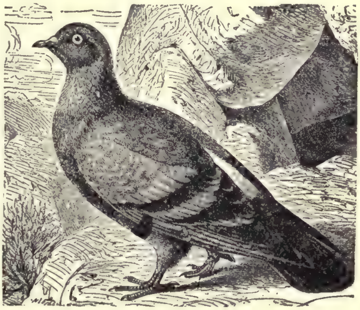
FIG. 161. Jungle fowl (*Gallus gallus*); native in tropical Asia.

(*l*) *Gruiformes.* Cranes and their relatives, including the rails and bustards. They have no true crop.

Cranes

(*m*) *Charadriiformes.* Plovers, snipes, curlews, gulls, terns, auks, and pigeons, — a mixed assemblage, declared by the anatomists to be more or less related! The marked differences between the several families have to do with the adaptation of the birds to particular modes of life — by the sea, on the rocks, or in the forest — and to particular feeding habits. At the same time it is remarkable how certain types, seemingly fitted only for a particular kind of existence, can modify their habits to suit the circumstances. Thus the curlew, with its extremely long and slender curved bill, is beautifully adapted for extracting mollusks or worms from deep mud or sand by the water's edge. In Labrador, however, Dr. Coues found the birds feeding almost entirely on the crowberry, the fruit of a hillside plant. The gulls, which we think of as exclusively marine, abound in the great basin between the Rocky Mountains and the Sierra Nevada, and in the early days of Utah saved the farmers by devour-

Plovers, gulls, and pigeons



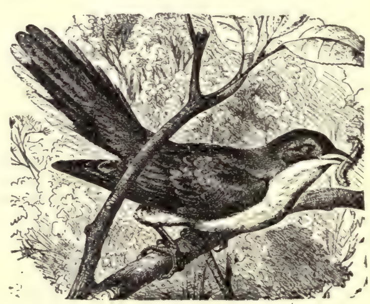
From "Animate Creation"

FIG. 162. The rock dove (*Columba livia*), the species from which the domesticated pigeons have been derived.

ing the hosts of grasshoppers. The pigeons, though typically arboreal, are by no means universally so; indeed, the domestic bird is derived from the rock dove, which inhabits rocky situations on the coasts and in the mountains of Europe. The passenger pigeon of America is now entirely extinct, though formerly it existed in countless myriads. The last one died at Cincinnati, Ohio, September 1, 1914. The dodo of the Island of Mauritius was a peculiar large pigeon, incapable of flight. In its isolated home it fared well until man arrived on the scene and ruthlessly destroyed the helpless and clumsy creatures. By 1693 it appears that the last dodo had perished.

Cuckoos and parrots

(*n*) *Cuculiformes.* Consisting of two suborders, one containing the cuckoos, the other the parrots. The European cuckoo is noted for its parasitic habits, its eggs being placed in the nests of other birds, which know no better than to rear the alien young. The little cuckoo, not content to share the nest with its rightful occupants, will even push the latter over the side, where they die in neglect upon the ground. This is merely an extreme case of a not uncommon phenomenon, that of one



From "Animate Creation"

FIG. 163. The yellow-billed cuckoo.

creature taking advantage of the instincts or habits of another. Slaves are enslaved as much by their own natures as by the force and cunning of their masters; characters which were entirely serviceable under different conditions, become the instru-

From "Animate Creation"

FIG. 164. The three-toed woodpecker.

ments of tyranny. The parrots, generally known by their characteristic bills and brilliant plumage, are widely spread over the earth, but mainly confined to warm or tropical regions. They are fruit and seed eaters, but the kea parrot of New Zealand has in recent times taken to killing sheep. The birds alight on the backs of the unfortunate animals, tear away the wool, and penetrate the flesh until they come to the fat in the region of the kidneys, which they devour. This transition to a flesh-eating habit is not so abrupt as we might suppose, since the parrots of this genus (*Nestor*) naturally feed on insect larvæ. The gray parrot of Africa is famous for its ability to talk, and even to sing in a fashion, following the human voice. The green American parrots also are clever talkers.

Owls, humming birds, and woodpeckers

(*o*) *Coraciiformes*. Another strange assemblage, containing such divergent types as the kingfishers, owls, goatsuckers, humming birds,

swifts, trogons, toucans, and woodpeckers. They are mainly arboreal, and the young are born blind and helpless. There are over 550 species of humming birds known, exclusively confined to the New World. In the Old World tropics their place is taken to some extent by the sun birds, which are, however, Passeriformes, with no real relationship to the humming birds. The fairy humming bird of Cuba is the smallest bird known, being only $2\frac{1}{4}$ inches long. The swifts, though resembling the swallows, are not at all closely related to them; the swallows are Passeriformes, and are structurally nearer to the sparrows than to the swifts.

Perching birds; sparrows and their relatives

(*p*) *Passeriformes.* The largest and highest group, which is among the birds what the Compositæ are among the plants. Wonderfully successful in the struggle for existence, presenting innumerable families and genera adapted to different modes of life, feeding on almost every kind of animal and vegetable matter, but

From "Animate Creation"

FIG. 165. A group of finches.

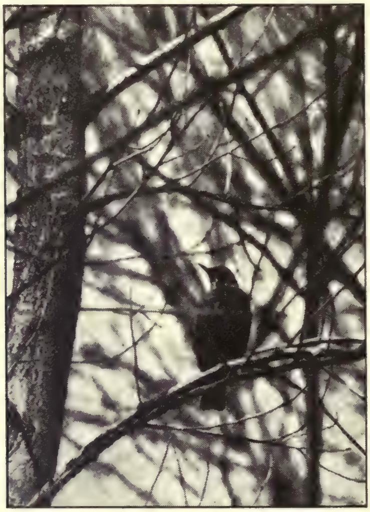
Photograph by E. R. Warren

FIG. 166. Rocky mountain jay (*Perisoreus canadensis capitalis*). This bird belongs to the family Corvidæ, which includes the jays, magpies, crows, etc. It is common in the higher mountains of Colorado, and makes itself very familiar about camps, amusing the campers by its impudent ways. It is often called the Camp Robber. Mr. Warren says: "Like all their family, they are great hands to carry away and hide food, and when fed a bird will usually eat a mouthful or two, take all it can hold in its bill, and fly off with it, presently returning to repeat the performance." It is interesting to note that a group of birds is characterized by its habits and psychology, as well as by the structural characters used for classification.

especially fitted to live on the multitudes of insects and the seeds and fruits of the higher plants. The name Passeriformes is from *Passer*, the European sparrow, but the term "sparrowlike birds" is inadequate, and conveys too narrow a meaning. It is better to think of them as perching birds, or song birds, or finches and warblers, but all such expressions cover only a part of the group. One great division is known to naturalists as the *oscines*, or singing birds, but affinity of structure compels us to include here so unmusical a creature as the crow! So also the birds of paradise, which cry *wok*, *wok*, *wok*, in the forests of the Aru Islands. Other oscines are the larks, flycatchers, robins, thrushes, wrens, swallows, waxwings, shrikes, vireos, jays, creepers, finches, warblers, and bluebirds. The so-called robin of America is a thrush, very dif-

ferent from the original robin redbreast of England. The bluebird is typically American, and is unknown in Europe.

It is scarcely possible to exaggerate the importance of birds for mankind. Aside from the value of their bodies as food and their feathers as ornament, they serve as the constant guardians of our crops. While an occasional hawk may raid the barnyard, and the cherries may suffer from the robins, all the damage done by birds to human interests is insignificant in comparison with the benefits conferred. The normal increase of injurious insects is sufficient to maintain each kind *in*



Photograph by E. R. Warren

FIG. 167. Western robin (*Planesticus migratorius propinquus*), Monument Valley Park, Colorado Springs, Colorado. This bird belongs to the thrush family, Turdidæ, and is very different from the true robin of England. It goes southward in the winter, returning early in the spring, though in Colorado a few birds remain throughout the year. Note the long bill, well adapted to the capture of cutworms in the soil. In Colorado it has seemed to us that the cutworms were worst when the ground was long covered by snow in spring, and we have thought that this might be largely due to the protection they thus gained from the robins.

Photograph by E. R. Warren

FIG. 168. Western tree sparrow (*Spizella monticola ochracea*), Colorado Springs, Colorado. A winter resident in Colorado, and a typical member of the large family Fringillidæ, which includes the sparrows, finches, etc. Note the short, thick bill, adapted for feeding on seeds, etc.

the presence of its natural enemies. This condition is spoken of as the "balance of nature," and when it is destroyed by the elimination of one side of the balance, — of the birds, — only disaster can result. In similar fashion, birds keep down the mice and other rodents, and hinder the increase of weeds by consuming vast quantities of their seeds. The preservation of birds thus becomes not merely a matter of sentiment but a public policy of the highest importance.

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CHAPTER FORTY-NINE

MAMMALS

Characters of Mammalia

1. Mammals are warm-blooded animals, differing from birds in lacking feathers and in having two condyles, or articulations of the skull with the first vertebra. The heart has four cavities, the right and left auricles and ventricles, and the body is usually covered with hair. The largest whales, fully 80 feet long, are the bulkiest of all living animals; but some mammals are so small that they can climb a stem of wheat. The group came into existence during the Mesozoic, and persisted for ages without very much development. With the dawn of the Tertiary era the development of modern mammalian life began, to produce in the course of three or four million years an enormous diversity of types, many of them highly specialized and very remarkable. Eventually man appeared, a mammal capable of looking back on all this long history and in some measure grasping its character and significance.

Egg-laying mammals

2. The class Mammalia is divided into two subclasses, the Prototheria or egg-laying mammals and the Eutheria or viviparous mammals. To the former are referred the fragmentary remains from the Triassic, which give us the earliest indication of mammalian life. Their egg-laying habits are of course only inferred, from their general resemblance to reptilian types. Even so, we should hardly have the courage to assume the former existence of oviparous mammals, were it not for the fact that such creatures still exist in the Australian region. These living Prototheria constitute the order *Monotremata*, and include the duckbill (*Ornithorhynchus*) ("bird bill" in Greek) of Australia, and the so-called spiny Anteaters (*Echidna* or *Tachyglossus*, and *Zaglos-*

sus) of Australia and New Guinea. The egg-laying habit of the duckbill may be directly traced to its

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 169. Echidna (*Echidna aculeata*).

reptilian ancestry, but the peculiar ducklike muzzle, suggesting a bird or a duck-billed dinosaur, is evidently a special adaptation. The teeth are absent in the adult, but present at an early stage; so the animal has evidently had toothed ancestors. The spiny anteaters are entirely different in appearance, having strong spines plentifully mixed with the fur, and the skull produced into a long, slender beak, very suggestive of a weevil.

Marsupials; the kangaroo, opossum, and their relatives

3. The Eutheria are divided into the *Marsupial* and *Placental* mammals. The marsupials are in some degree intermediate between the Prototheria and the placentals. The young are born in a very rudimentary condition, and are not nourished by a typical placenta or base of attachment to the mother. These little-developed young are nearly always concealed in a pouch or marsupium, where they are fed with the parent's milk.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 170. Great gray kangaroo (*Macropus giganteus*).

There are other characteristic features of the skeleton and teeth, but within the limits of the Marsupialia we find the greatest diversity of outward form and of habits. Nature, as in so many cases, produces species adapted to all sorts of life and consequently superficially resembling others which have parallel habits but are not at all closely related. Australia is the present home of marsupials, but America also possesses examples, the most familiar being the opossum. The opossums, of which there are several kinds, inhabit both North and South America, living in trees. The survival of so many marsupials in Australia has been possible because the region has been cut off from the rest of the world for ages, and the higher mammals have for the most part failed to reach it. In Australia we find the kangaroos, wombats, phalangers, pouched mole, and many other forms. It used to be said that the Australian marsupials simulated almost every type of land mammal except the mole, and it was a matter of great interest to zoölogists when at length a molelike species (*Notoryctes*) was discovered.

Placental mammals

4. The Placental or higher mammals, including all the most familiar forms, are nourished within the body of the mother, and are born in an advanced state of development. There are numerous orders, of which the following are the most important:

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

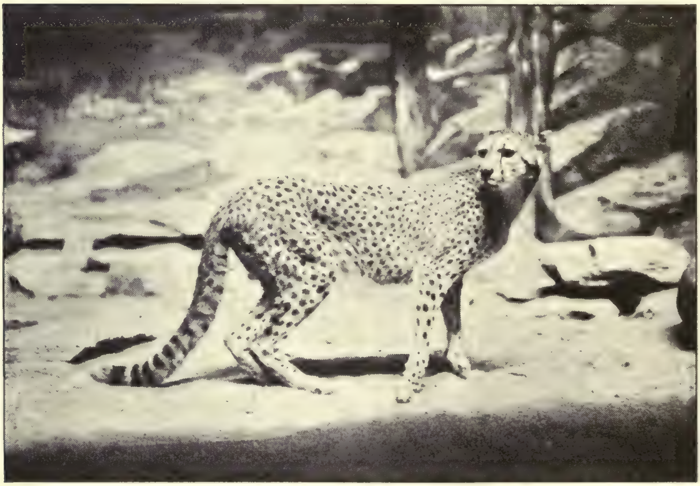
FIG. 171. European hedgehog (*Erinaceus Europaeus*), one of the larger Insectivora.

(*a*) *Insectivora.* The Insectivores, or insect eaters, include the moles, shrews, and hedgehogs, the last confined to the Old World. There are also various isolated and peculiar genera, such as the *Solenodon* of Cuba and Haiti, a creature with a bristly, pointed snout and long, thick tail. In the popular mind some of these animals, such as the shrews, are confused with the mice, but a glance at their sharp, pointed teeth shows the incorrectness of this association. They are actually nearer to the bats, different as these appear. The golden moles of South Africa, with their metallic-looking fur of golden bronzy, greenish, or violet shades, are beautiful and remarkable animals. Representatives have been found fossil in North America, but are of course known only by the bones. **Insectivores**

(*b*) *Chiroptera.* The bats, easily recognized by their powers of flight. Many are insectivorous, but **Bats, flying mammals**

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 172. Barbary lion (*Felis leo*).



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 173. Cheetah or hunting leopard (*Cynælurus jubatus*). In Asia it is trained for the chase of the antelope.

others feed on fruit, and are sometimes very destructive in tropical countries. The vampire bats of Central and South America are blood-suckers, and have a peculiar tubular stomach, adapted for the digestion of blood.

(*c*) *Carnivora*. The carnivores, with sharp teeth and claws. The principal families are:

Carnivores, flesh-eating mammals

(i) *Felidæ*. Lions, tigers, cats, and their relatives. The largest American species are the mountain lion (or puma) and the jaguar; the latter beautifully spotted, and confined to the tropical and subtropical regions.

(ii) *Hyænidæ*. Hyenas, belonging to the Ethiopian and Oriental regions.

(iii) *Viverridæ*. Mongooses, civets, etc. The mongoose was introduced from the Old World into Jamaica to destroy the rats, which were seriously injuring the sugar cane. This it did, but it then turned its attention to the native birds. The destruction of the birds is supposed to have led to the great increase of ticks in recent years, though it is proper to state that the ticks were doubtless mostly or all introduced by man. The case of the mongoose in Jamaica is therefore cited as an illustration of the danger of disturbing the "balance of nature."

(iv) *Mustelidæ*. Martins, weasels, wolverines, badgers, skunks, and otters. The skunk, with its handsome black and white fur, illustrates the theory of warning coloration.

Photograph by E. R. Warren, "Mammals of Colorado"

FIG. 174. Long-tailed Texas skunk (*Mephitis mesomelas varians*), Crested Butte, Gunnison County, Colorado. The skunk, well known for its odor, differs from most animals in its striking black and white coloration. This is believed to be "warning coloration," enabling would-be enemies to recognize the animal easily and, recalling former experiences, let it alone. Thayer suggests, however, that the peculiar ornamentation breaks up the outline of the creature, as it were, and is actually deceptive or concealing. The reader may form his own opinion from the picture.

(v) *Ursidæ.* The bears. The polar bear is placed in a distinct genus from the brown, grizzly, and black bears. The typical grizzly bear described by Lewis and Clark appears to be extinct, though related species exist in North America.

(vi) *Procyonidæ.* Raccoons; characteristic American animals. The Asiatic panda is referred to the same family.

(vii) *Canidæ.* Dogs, wolves, coyotes, and foxes.

The suborder *Pinnipedia* includes the aquatic carnivores, — seals, sea lions, and walruses. The name "walrus" is a modification of a Scandinavian word meaning "whale horse." The upper canine teeth in

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 175. Black-footed ferret or weasel (*Mustela nigripes*), representing the family Mustelidæ.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 176. Arctic fox (*Alopex lagopus*), found in arctic regions.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 177. Hunting dog (*Lycaon*); South and East Africa.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 178. Raccoon dog (*Nyctereutes procyonides*); Japan and Northeast Asia.

this genus (*Odobænus*) are modified into immense tusks, which are used in digging for food and in fighting. Although the animals are so large, they feed mainly on bivalve mollusks which they find in the mud and sand of northern shores.

Rodents, gnawing mammals

(*d*) *Rodentia*. Rodents, or gnawing animals, best known by their peculiar teeth. The canine teeth are absent, while the incisors grow from persistent pulps, grinding against one another. When, as occasionally happens, an upper incisor is knocked out, the lower one opposed to it continues to grow in a circle, eventually entering the brain and killing the animal. The surfaces of the grinding teeth are more or less flattened, not conical as in carnivores and insectivores. The enamel pattern is often elaborate. Rodents are the dominant and diversified mammals, in this respect corresponding to the Passeriformes among the birds. They include the squirrels, chipmunks, woodchucks, beavers, gophers, mice, rats, porcupines, guinea pigs, and many lesser-known forms. The guinea pigs

Photograph by E. R. Warren, "Mammals of Colorado"

FIG. 179. Pika (*Ochotona saxatilis*); Irwin, Gunnison County, Colorado. The pikas, often called conies, are found among rocks in the mountains of the northern hemisphere from Eastern Europe to Western America. Their cheerful cries may be heard in the summer far above timber line. These animals constitute a very distinct family, related to the rabbits, but with short ears and no tail.

Photograph by E. R. Warren

FIG. 180. Mountain rat (*Neotoma cinerea orolestes*); Colorado Springs, Colorado. This is a native American rat, easily distinguished by the bushy tail from the Norway or brown rat, which has been introduced into this country from the Old World. The mountain rat is often troublesome in houses, from its habit of carrying off spoons and other articles. It is sometimes called the trade rat, because it is said that it always leaves something in exchange for what it takes. The explanation is, that if it is carrying a stick and finds a bright object like a spoon or fork, it will drop the stick and take the more attractive thing.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 181. Branick paca (*Dinomys branicki*); a rare rodent from Peru, long known only from a single specimen.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 182. American beaver (*Castor canadensis*).

are of course not pigs, and they do not come from Guinea; the original intention was to say Guiana pig. They constitute a peculiar South American genus, and should be known as cavies (*Cavia*). The Norway rat and house mouse are of Old World origin, and have been introduced into America by man. The native American rats and mice belong to different genera, although the genera *Castor* (beavers), *Marmota* (marmots and woodchucks), *Sciurus* (squirrels), and some genera of voles are common to the New and Old Worlds. The prairie dog (*Cynomys*, meaning "dog mouse") is peculiar to North America; it is essentially a squirrel modified for life on the treeless plains. The rabbits, hares, and pikas are usually placed with the rodents, from which they differ by having two pairs of incisor teeth in the upper jaw. Anatomical evidence has lately been presented, which seems to show that these animals constitute a group distinct from the true rodents and of quite independent evolution.

Sloths, anteaters, and armadillos

(*e*) *Edentata*. Sloths, anteaters, and armadillos, all American. The name of the order means "toothless," and is accurate as applied to the anteaters, but not to the others. The ground sloths, now all extinct, but living within comparatively recent times, were immense animals, comparable in size with elephants and rhinoceroses. There is evidence that a species of these animals was contemporaneous with man in South America, and pieces of its skin, with hair attached, have been discovered in a cave. The armadillos are remarkable for

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 183. Sloth (*Cholœpus hoffmanni*); Central America. Called the two-toed sloth, because the anterior limbs have only two functional toes with claws; but the hind limbs have three claws, as the picture shows.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 184. Great ant-eater (*Myrmecophaga jubata*); tropical America.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

Fig. 185. Nine-banded armadillo (*Dasypus novemcinctus*); Southern Texas and southward.

their mode of reproduction; a single fertilized egg gives rise to several individuals, an exaggeration of twinning known as *polyembryony*.

Monkeys and man

(*f*) *Primates.* Lemurs, monkeys, and man; mostly tree-inhabiting animals, with nails on the fingers and toes, instead of claws or hoofs. The lemurs today principally inhabit Madagascar, but primitive species once existed in North America, as shown by their fossil remains. The monkeys are divided into the *Platyrrhine* (broad-nostril) and *Catarrhine*

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

Fig. 186. Lemur (*Lemur varius*); Madagascar.

(narrow-nostril) group, — the former peculiar to the New World, the latter to the Old World. The higher apes and men are to be associated with the Old World group. The tail in many of the South American monkeys is prehensile; that is, it can be used to hold on to a branch, as the animal swings and leaps through the forest. In the Old World no monkeys have a prehensile tail, and in the anthropoid (manlike) apes or *Simiidæ* there is no tail at all.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 187. Orang-utan (*Simia satyrus*); Sumatra and Borneo.

Hoofed mammals

(*g*) *Artiodactyla*, or even-toed ungulates (hoofed animals). The (morphologically) third and fourth toes are almost equally developed, the others small or absent. This order includes the following important families:

(i) *Suidæ*. Pigs, natives of the Old World.

(ii) *Tayassuidæ*. Peccaries, the American representatives of the pigs.

(iii) *Hippopotamidæ*. Hippopotamus

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

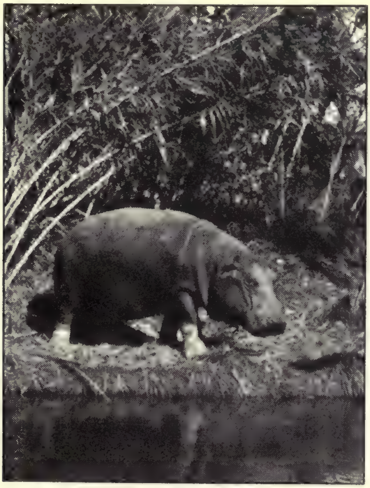
FIG. 188. African bush pig (*Potamochœrus porcus*). Family Suidæ.

(the name means "river horse"), now found in Africa, but formerly extending to Europe and Asia.

(iv) *Camelidæ.* Camels, found in Central Asia and North Africa; and llamas, found in South America. This discontinuous distribution of the family would be astonishing, did we not know from fossils that camels of many genera formerly abounded in North America.

(v) *Giraffidæ.* Giraffes and the okapi (*Ocapia*), now confined to Africa.

(vi) *Cervidæ.* Deer, including the reindeer, caribou, and moose. The name elk (*Alces*) properly belongs to the moose, and is wrongly applied to the American wapiti, which is a close relative of the



Photograph by S. S. Flower

FIG. 189. Hippopotamus (*Hippopotamus amphibius*) in the Giza Zoölogical Gardens, Egypt.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 190. Axis deer (*Axis axis*); India. Family Cervidæ.

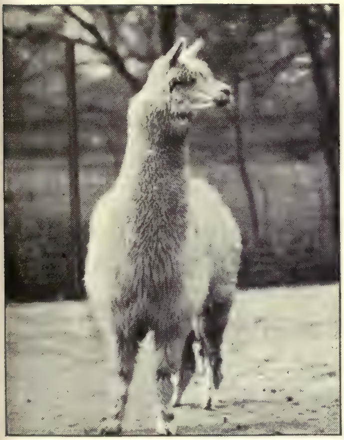
Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 191. Pronghorn antelope (*Antilocapra americana*)

red deer of Europe. On the other hand, the black-tail and white-tail deer of the United States represent a genus not found in the Old World.

(vii) *Antilocapridæ.* The pronghorn antelope of our Western plains, peculiar to North America, and not closely related to the African antelopes.

(viii) *Bovidæ.* Oxen, sheep, goats, musk oxen, chamois, and true antelopes. The African and Indian buffaloes are allied to the oxen, but are quite different from the American buffalo, properly called the bison. The latter animal, differing little in structure from the domestic ox, though of very characteristic appearance, is represented by a similar species



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 192. Alpaca (*Auchenia pacos*); Andes of Peru and Bolivia. Family Camelidæ.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 193. Rocky mountain goat (*Oreamnos montanus*). Family Bovidæ.

in Europe. In both cases the intervention of man has been necessary to preserve the animal from complete extinction at the hands of man himself. The mountain sheep of our Western states are true sheep (*Ovis*), and are closely allied to others found in Asia and the region of the Mediterranean. The true goats (*Capra*) belong to the Old World; the Rocky Mountain goat is quite different, and is more nearly related to the chamois of European mountains.

(*h*) *Perissodactyla.* Odd-toed ungulates, including the horses, tapirs, and rhinoceroses. The rhinoceros group, now confined to the Ethiopian and Oriental regions, was once richly represented in America.

(*i*) *Proboscidea.* Elephants, including mastodons and mammoths.

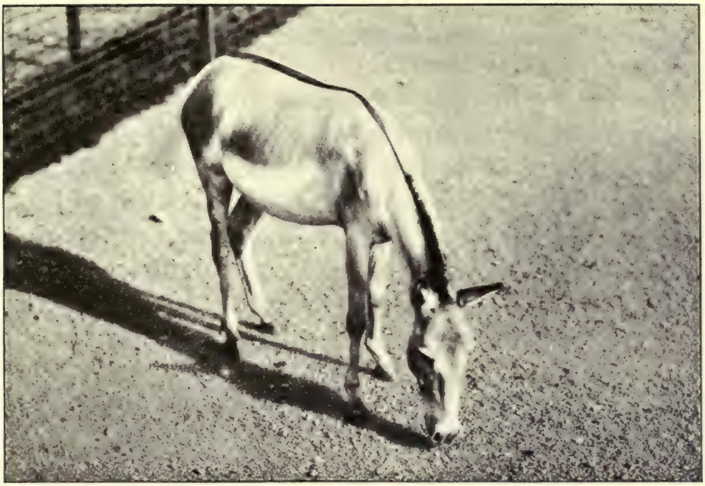
(*j*) *Sirenia*, which are aquatic derivatives of the ungulate type, as the seals are of the carnivorous group. The living forms are the manatee and dugong.

Whales

(*k*) *Odontoceti*, or toothed whales, including dolphins and porpoises.

(*l*) *Mystacoceti*, the whalebone whales.

The arrangement of the orders of mammals, as here given, does not represent the course of evolution in any accurate way, nor is it possible to do so in a single series. The evolution of the mammals has been treelike or fanlike, the several orders diverging along their own paths, and not as a rule giving rise to any other. This can be readily demonstrated by a study of the struc-



Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 194. Persian wild ass; showing the dorsal stripe which appears to be a primitive character in the Equidæ.

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 195. Grant's zebra (*Equus burchelli granti*).

tural features; thus the rodents, with modified teeth and the canines lost, could not possibly give rise to carnivora, primates, or artiodactyla. The artiodactyla and perissodactyla, with their modified feet, could not be ancestral to primates, carnivora, or rodents. Although the details of evolution, and consequently of classification, are to be determined only by minute and persistent research, or may elude us altogether, many of the broad features are so obvious that they may be appreciated by any beginner.

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CHAPTER FIFTY

THE EVOLUTION OF THE HORSE AND THE ELEPHANT

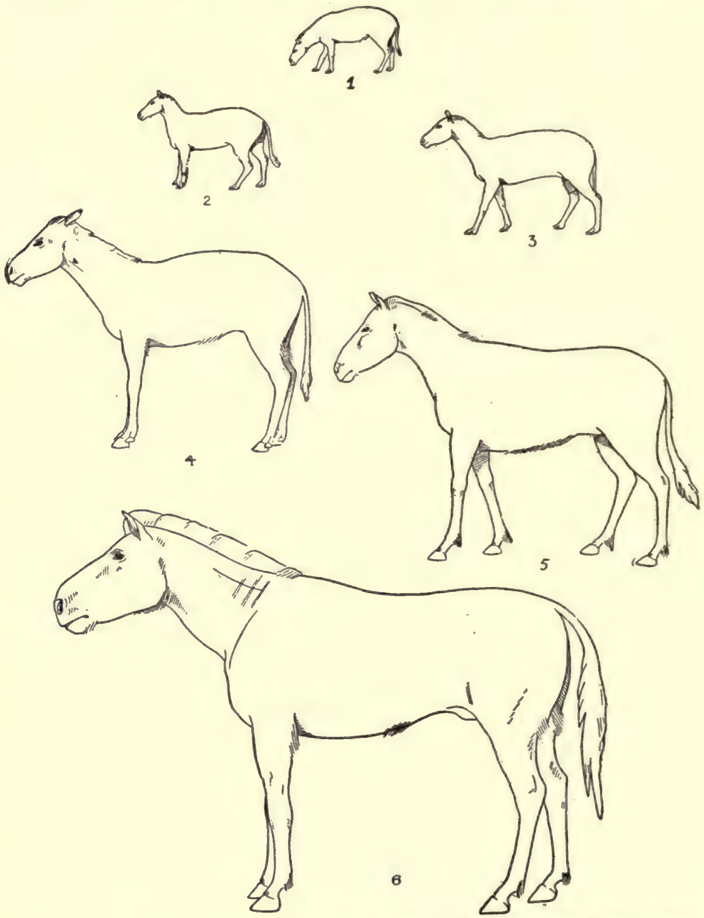
Structure of the horse

1. WERE the horse not a common animal, to be seen any day on the streets, it would be regarded with wonder and amazement. The Mammalia in general, including man, have five toes or digits. This number is never increased, except in monstrosities, but it may be decreased. In the horse, only a single toe is left on each foot, and the greatly enlarged toenail is the hoof. The teeth of the horse are scarcely less remarkable. Adapted for grinding hard food, they are very long, with an extremely complicated enamel pattern. The surfaces are ground down during life, and as the appearance differs at different levels, it is possible to tell the age of a horse by its teeth. The mane and tail are also peculiar, and there are many other interesting structural features. Added to all these are the psychological characteristics, — the wonderful combination of intelligence with docility, which makes the animal useful to man. A well-known breeder and lover of horses was so moved by all these excellences, that he declared that the one great error in evolution was the derivation of man from a mischievous, ill-behaved creature of the monkey group, instead of a majestic, sagacious beast such as the horse!

Ancestors of the horse

2. In any dispute over the fact of evolution, it would be natural to cite the horse as presenting special difficulties. How could it be that an animal so peculiar had been derived from any other type? Fortunately, however, it is in this very group that we have one of the most complete evolutionary series, preserved in the form of fossil bones. Going back to a period fully three million years ago, we find in the Eocene strata of the Rocky Mountain states remains of an animal barely a foot

high at the shoulder, and having rather the appearance of a small dog. This little beast is named *Eohippus*, which literally means "the horse of the dawn," — the



From Lull's "Yale Collection of Fossil Horses"

FIG. 196. Sketches showing the evolution of the horse from the primitive four-toed ancestor to the last American species. Restored by Dr. R. S. Lull from specimens in the collection of Yale University. 1, *Eohippus*, Lower Eocene; 2, *Orohippus*, Middle Eocene; 3. *Mesohippus*, Oligocene; 4, *Merychippus*, Miocene; 5, *Pliohippus*, Pliocene; 6, *Equus scotti*, Pleistocene.

beginning of horse life. It is often called the first horse, but of course it was not a horse at all, in any proper meaning of that word. The toes were already reduced from the primitive number, but there were four on the front foot, three on the hind. The teeth were short-crowned, without a complicated enamel pattern. Such an animal was well adapted to the warm, moist climate of the period, feeding on soft food and traveling on soft ground. Had conditions remained unchanged, there would presumably have been no evolution of the horse.

Lines of development

3. In the Rocky Mountains the rocks of the Tertiary period have been unusually well preserved, and from them it has been possible to obtain a remarkably complete series of fossils. Thus it is that the history of the horse has been made out, and although the family belongs today to the Old World, we feel assured that it developed in the New. Without going into many details, it will suffice to say that in successive deposits we can trace a series of forms leading from the small *Eohippus* to the horse of modern times. In the foot there is a gradual reduction of the toes. In the teeth the enamel pattern becomes increasingly complex, and the crowns are lengthened. There is a steady, almost regular increase in size. Thus the species of the horse family, when found as fossils, are especially valuable to the geologist as time markers. They indicate *relative* time only, of course, — like a clock the hands of which moved, but on the face of which were no marks to indicate the seconds, minutes, or hours.

The theory of orthogenesis

4. Naturalists, recording evolutionary processes such as that just described, have sometimes postulated what they called *orthogenesis*, the first part of the word meaning "straight" or "regular," as in *orthodox*. This implies that evolution follows a predetermined path, which

was laid out for it in the beginning. Thus, the horse group was to *increase* in size, *decrease* the number of its toes, etc. It actually behaved as if following out a program planned in advance. The idea is not inherently absurd, since this is the course of *individual* development; and it may well be imagined that there is something in the nature of a particular kind of protoplasm, that will lead it to vary in a certain direction. Indeed, we know that it does not vary in *all* directions; thus we cannot get a genuinely blue rose. It is to be noted, however, that the evolution of the horse group is also strictly along the lines of *adaptation*. The climate became cooler and drier; the animal became an inhabitant of the plains. The solid hoof is adapted for running on hard ground, for receiving the impact of the heavier body; also for kicking the carnivorous enemies which had in the meanwhile evolved to prey upon the horse. The long-crowned, hard teeth are adapted for feeding on the vegetation to be found in open, dry places, and what might be regarded as a difficulty has been so completely overcome that the animal now needs the type of food for which it is specially fitted. The whole history is one of adjustment to conditions, and the evolutionary process could not have taken place in the *Eohippus* environment, for the simple reason that the changes would all have been detrimental, leading eventually to extinction. In the case of the elephant group, as we shall presently see, there was the same apparent orthogenesis, until a certain structure became useless, when the whole process was reversed.

Extinct American horses

5. Eventually the horse group reached the Old World, undoubtedly by way of the land bridge to Asia which then existed in the north. During much earlier times the primitive horselike types had existed on both sides

of the world, the American *Eohippus* being represented in Europe by an animal called *Hyracotherium*, or coney beast. It is therefore uncertain where the group actually originated. Nevertheless, the development of the true horse can be traced in America, and in prehistoric times numerous kinds of horses, large and small, existed in this country. One of them, found in Texas, had teeth larger than those of the largest living race. In northern Texas and the adjacent parts of New Mexico was a type of horse which has been named *Equus scotti*, after the palæontologist W. B. Scott, who has contributed much to our knowledge of fossil mammals. This species is known by very complete skeletons, so that it is possible to form an excellent idea of its characters. Its bones are remarkably like those of the domestic horse, but it was relatively long-bodied and short-legged, with a large head. Why it became extinct, we do not know. Certainly the climate was not unfavorable, as horses ran wild in vast numbers when later introduced by the Spaniards. Man could hardly have been responsible, for aboriginal man did not destroy the game animals of this continent. Possibly some disease destroyed the horse in America, leaving no proof of its existence.

Old World horses

6. In the Old World the genus *Equus* (Latin, a horse) presents a number of very distinct types, including the horses proper, the asses, and the zebras. The typical or true horses formerly abounded in Europe and Asia, but today only one wild species exists. This animal, found in western Mongolia, was named *Equus przewalskii*, after the well-known Russian explorer, Przewalski, who obtained the first specimen nearly 40 years ago. It is a pony with a relatively large head (here suggesting the *Equus scotti*), a short, erect mane, and a tail with

Photograph by E. R. Sanborn, N. Y. Zoöl. Soc.

FIG. 197. Przewalski wild horse (*Equus przevalskii*).

rather short hair basally, though ending in a long tuft. The general color is dun, and there is a distinct stripe down the back, while shoulder stripes and barring on the upper parts of the legs may frequently be observed. It is an interesting fact that these same markings may often be found on broncho ponies of the southwestern United States, derived from the old Spanish stock which formerly ran wild.

Origin of the domestic horse

7. The domestic horse was named by Linnæus *Equus caballus* (from *caballus*, an old name for the horse, perpetuated today in the Spanish *caballo;* note also *caballero*, a gentleman, i.e., a man who rides a horse). It did not occur to Linnæus that more than one species was involved, but, as in the case of dogs and cats, it appears that the domesticated animal is derived through crossing from two or more originally wild forms. Evidence of this is found in the prehistoric drawings on the walls of caves in France and Spain, made by the Crô-Magnon man. These drawings, while not very exact, are clever

and evidently characteristic, and suggest that even in those remote times the straight-faced and "Roman-nosed" types were perfectly distinct. This idea is also supported by the skulls of various extinct horses which have been found in Europe. How the horse first came to be domesticated, we do not know, but some of the prehistoric drawings appear to indicate its use as a pack animal. Some adventurous individual, who had perhaps employed a horse in this manner, one day conceived the idea that it might also carry him, and leaped astride. The astonishment of his fellows at this feat appears to be preserved in ancient legends of a being half horse and half man.

The Celtic pony

8. In many ways opposite to the Przewalski horse is the Celtic pony, or *Equus celticus*. This small animal, now known especially from Iceland, exists only in a state of domestication, but it has marked peculiarities. In color it is similar to the Przewalski horse, but the mane is long and consists of a central and a lateral portion. The tail, instead of being short-haired at the base, is there covered by a great tuft. Professor J. C. Ewart of Edinburgh, who first clearly distinguished the Celtic pony, observed that the bunch of hair at the root of the tail served to protect that region from rain and snow. In a storm, while other horses made for shelter, the Celtic ponies simply turned their hind quarters to the blast and went on feeding unconcernedly. Were they not able to do this, they would scarcely be able to prosper in the damp and stormy regions which they inhabit.

On the legs of horses may be seen certain callosities or pads, the upper ones being called "chestnuts," the lower, "ergots." The latter seem to represent rudiments of the hind foot pad; but the former, on the inner side of the leg, must apparently be explained in some

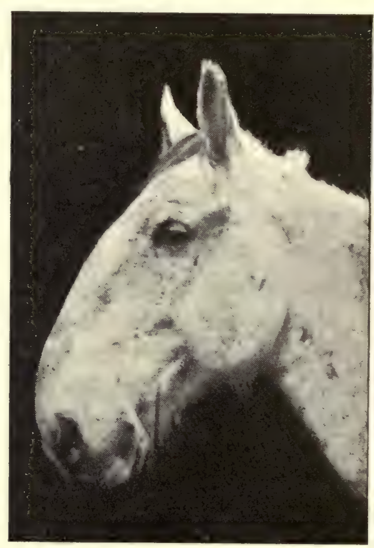
other way. It has been suggested that the chestnuts represent glands which exist in deer, which function as scent organs. The habits of the horse would make such glands superfluous, but they were perhaps functional in an ancestor. The Celtic pony has entirely lost the ergots and the hind chestnuts, and hence Professor Ewart regards it as a specialized member of the genus.

The Arab horse

9. Another very distinct type is the Arab, which is the most beautiful and interesting of all horses. It has been named *Equus asiaticus*. Whether it originated in Asia or northern Africa is much disputed, but the Libyan tribes appear to have possessed such an animal at a time when the Arabs were quite without horses. The Arab is long-legged, with the head held high and the tail raised when in motion, as may usually be seen in

Photograph by Professor J. C. Ewart

FIG. 198. "Sherkieh," an Arab of the Hamdani Simri strain.



Photograph by Professor J. C. Ewart

FIG. 199. "Romano," a type of horse similar to that figured by prehistoric men in the Combarelles cave, France.

equestrian statues. The profile of the face is distinctly concave, and the short skull is broad between the eyes. The tail vertebræ are reduced, and there are only five instead of six lumbar vertebræ. The English thoroughbred horse, remarkable for its speed, owes much of its quality to Arab blood.

EVOLUTION OF THE ELEPHANT

Discovery of ancestors of elephant in Egypt

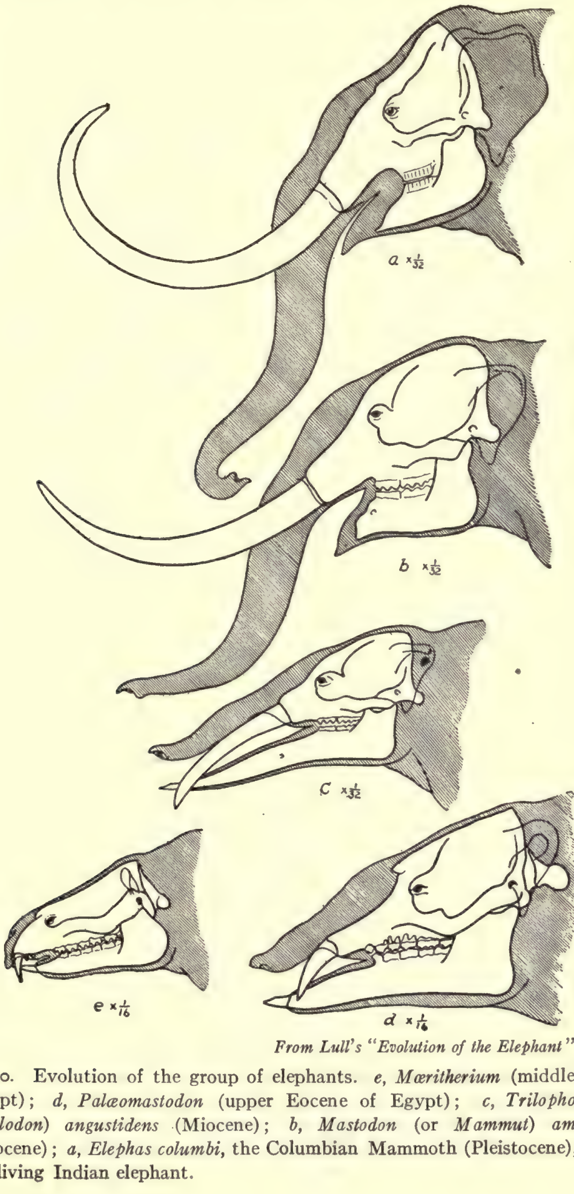
1. The evolutionary history of the elephant was long unknown, but in comparatively recent years the Fayum desert of Egypt has yielded a series of fossil animals which serve to connect the highly specialized elephant of today with much more primitive types. Dr. C. W. Andrews of the British Museum, who obtained most of these fossils, has given a full discussion of the subject. The oldest known member of the series is called *Mœritherium*, after the ancient Lake Mœris, near which it was discovered. It was more or less tapirlike, very small in comparison with the elephants, with extremely short tusks. Its relationships with still earlier forms cannot be made out, but there are certain resemblances to the living manatee in the details of structure, though not at all in appearance. After a time this type gave place to the *Palæomastodon* (old mastodon), a larger animal with longer tusks, and the lower jaw extended outward, apparently for digging. Next we have the *Trilophodon*, still larger, with long, slightly curved tusks, and enormously lengthened lower mandible, which must have served as a regular plow. This type of animal was so successful that it spread far and wide, and even invaded North America. The arrival of the Proboscidea, or elephant group, in America took place in the Miocene, and marks an important date in the geological series.

Lines of development

2. So far, evolution was apparently orthogenetic, the size steadily increasing, while the tusks grew longer and the trunk doubtless developed. Although the trunk is of course lacking in the fossils, some idea of its development may be gained by a study of the surfaces for muscular attachment. Now, however, while the tusks became still larger, and curved upward, the lower jaw or mandible reversed its former development and became very short. It appears certain that the mode of securing food had changed. The animal no longer gained its food principally by digging or uprooting plants, but used its long trunk to secure branches from the trees or "gather in" the long herbage. The mandible of *Tetrabelodon*, if retained, would have been a useless luxury, or indeed a detriment. The teeth, now reduced in number, became extraordinarily massive, with eventually a very complicated pattern of transverse ridges of enamel. More powerful grinding organs could hardly be imagined. The great tusks, used by the males in fighting and also employed in digging, are composed mainly of solid dentine, furnishing to man the familiar substance ivory. The skull is short and of great height, with an enormous development of the frontal sinuses or air spaces. In consequence of this structure, blows on the front of the head do not kill the animal, and bullets fired at the forehead rarely reach the brain. The brain, though small for such a large animal, is actually much larger than that of man. The mental development of the elephant is also noteworthy and, as in man, may be connected with the ability to handle objects. Had the elephant two trunks instead of one, as a man has two hands, who can say what it might become?

Mastodon and mammoth

3. The mastodon and mammoth are extinct elephants. The mastodon is especially distinguished from



From Lull's "Evolution of the Elephant"

FIG. 200. Evolution of the group of elephants. *e, Mœritherium* (middle Eocene of Egypt); *d, Palæomastodon* (upper Eocene of Egypt); *c, Trilophodon* (or *Tetrabelodon*) *angustidens* (Miocene); *b, Mastodon* (or *Mammut*) *americanus* (Pleistocene); *a, Elephas columbi,* the Columbian Mammoth (Pleistocene), related to the living Indian elephant.

the modern elephants by the structure of its teeth, which have not nearly so many transverse ridges and are thus more primitive. The mammoth, on the other hand, is a veritable elephant, belonging to the same genus (*Elephas*) as the Indian species. The Indian elephant is hairy at birth, and the mammoth was coated with long hair at maturity. Not only do the drawings of ancient man show the mammoth as a hairy beast, but frozen bodies of these animals have been found in Siberia, preserved in cold storage so perfectly that the flesh was still edible. Even the contents of the stomach have been secured, showing that the food consisted of such plants as still exist in those northern regions. These discoveries illustrate the possible mistakes which may be made in reasoning about past climates from fossil remains. Modern elephants being tropical, one would naturally infer that wherever these animals existed, tropical conditions prevailed.

North America, in Pleistocene time, had three distinct species of elephants or mammoths. Of these the true mammoth, *Elephas primigenius*, was not the largest. The other two are named *Elephas columbi* (after Columbus) and *Elephas imperator* (emperor). Their remains are widely scattered over the country.

Living elephants

4. Living elephants belong to two groups. The Indian elephant is familiar as a domestic animal in oriental countries. The African elephants, remarkable for the extremely large ears, have been placed in a distinct genus, *Loxodonta*. There are several distinct types, but authorities differ greatly in their judgment as to the number of species. It is naturally difficult to secure a good collection of elephants, and consequently opinions have been based on inadequate materials.

CHAPTER FIFTY-ONE

THE EVOLUTION OF MAN

1. It is impossible for any of us, unless we happen to be kings or their kindred, to trace our ancestry back many generations. In any group of Americans gathered together, it will be found that few know the family names of their grandmothers, and almost none those of their great grandmothers. We all know, of course, that the stream of life has been continuous, that one family is not any older than another, — that all are of incalculable antiquity. If it is thus difficult or impossible to trace our human ancestry, how can we expect to succeed with the prehuman, and recover traces of those beings whose existence millions of years ago was necessary in order that we should be here today? **Our ignorance of human ancestry**

2. No biologist supposes that it will ever be possible to ascertain all the details of human evolution. Yet the general outline of the process is recognizable. First of all, the human individual, in his development, appears to repeat more or less the history of animal life, — to climb, as Huxley said, his own family tree. Thus all animals, including man, begin as a single cell, agreeing in its general features with the lowest forms of life known, the permanently one-celled organisms called Protozoa and Protophyta. All many-celled creatures can be traced back to the one-celled condition at the beginning of their existence, and we can hardly doubt that the evolutionary process began in a similar manner. Thus the first stage of human evolution may be described as protozoan. **Development of man indicates the character of his evolution**

3. Development proceeds through segmentation. Numerous cells are formed, which, instead of separating and becoming isolated individuals, as in the Protozoa, **Early stages of development and evolution**

remain together to form a coöperative unit. In course of time a cavity is formed within the developing organism or embryo, communicating with the outside by a a single opening, called the blastopore. In a general way this stage may be said to correspond with that of the adult medusa or jellyfish, or with the sea anemone. These lowly animals are shaped more or less like a bottle, with a large cavity opening only at one end. It thus appears probable that our very remote ancestors passed through a cœlenterate stage, though of course this cannot be demonstrated as a fact. The blastopore, which is situated at what becomes the hind end of the body, presently closes, and the permanent anterior and posterior openings of the alimentary canal are formed by new depressions or pits, which meet and become continuous with the ends of the central cavity. When this has occurred, the embryo has reached what is in effect a worm stage; and although there is no close resemblance to any particular kind of worm, we can hardly doubt that we have passed through a wormlike condition in the course of our evolution.

The cœlenterate stage

All this may seem highly speculative, but from our knowledge of animal structure and development it appears impossible to imagine any other path of evolution than the one suggested. Thus, for example, while a non-scientific person might ask whether the first animal was not after all wormlike, or fishlike, the so-called lower forms resulting from degeneration and disintegration, the biologist readily perceives so many difficulties in the way of such a theory that he cannot even class it among the possibilities.

Evolution from a wormlike stage

4. When we leave the worm stage, our principal difficulties begin. From this point until the vertebrate type is distinctly formed, the path of evolution is ob-

scure, and great differences of opinion prevail. The Amphioxus does indeed illustrate a prevertebrate stage, but of course this animal, now living in shallow seas, must be quite different in detail from our actual ancestor. We can hardly hope that fossils will be found which will throw much light on this question, but the patient study of existing animals may give us additional clews. At all events our more or less wormlike ancestor developed a notochord, a dorsal nerve cord, and a system of breathing (in water, of course) by means of gill arches. In a dramatic treatment of the event, we have supposed this primitive creature to say:

> We are not much to look at, but we are
> All in the way of progress.
> Our backs are stiffened by a notochord, and all above
> A slender nerve cord runs from fore to aft,
> Prophetic of a brain. This tiny spot, this little speck of black,
> Will some day be a pair of eyes, to knowingly survey the world,
> While these gill slits, ranged on each side, already serve
> To liven us with oxygen, gleaned from the waters flowing through them.
> All in the way of progress to be vertebrates, and in days to come
> Perchance, some creature with a soul.

Early vertebrates

5. Reaching the vertebrate stage, we cannot doubt that the first forms were fishlike, and lived in water. The human embryo, at an early stage, shows structures corresponding to the gill bars, though no longer functioning as such. One of these ultimately becomes the mandible or lower jaw. Although we thus postulate a fish stage in our ancestry, we do not suppose that this includes anything resembling the higher fishes of today. In the modern fishes of highly specialized type, such as the perch, the posterior paired fins have come to lie close to or even beneath the anterior or pectoral pair; and many other developments have taken place which lead altogether away from the human type of structure.

The amphibian, the next step in the path of evolution toward man, unquestionably arose from a relatively primitive type of fish.

Discovery of the land by man's ancestors

6. With the appearance of amphibians came the discovery of the land by vertebrates, as we have already indicated. Next came the reptiles, capable of reproducing without recourse to water. From these arose the mammals, but not from anything like the modern reptile. As in the case of the fishes, the higher reptiles, with their single occipital condyle and other peculiarities, have gone off on a path which cannot possibly lead to anything mammalian. It is only by reference to very ancient fossil forms that we can get any accurate clew to the course of events. This we seem to find in the cynodont or dog-toothed reptiles of the South African Mesozoic, — animals which possessed paired occipital condyles, and the teeth differentiated into incisors, canines, premolars, and molars.

Egg-laying mammals

7. The first true mammals, or Prototheria, were warm-blooded, hairy, egg-laying creatures. The modern Australian duckbill (*Ornithorhynchus*) is a specialized member of this group. The principal food of these animals was probably insects, and it is perhaps a fact that the development of the mammalian type was largely aided and made possible by the increasing development and variety of insect life. Still in the Mesozoic age, primitive marsupial mammals arose, now viviparous, but producing the young in a very underdeveloped condition, so that they had to be nourished in the maternal pouch. Such animals, represented today by the opossums, were probably also insect feeders, like the South American *Marmosa*. They were also probably arboreal, living in trees; and in accordance with these habits certain changes took place in the

structure of the shoulder girdle, which profoundly influenced subsequent developments. Thus the coracoid bone, so prominent in birds, became reduced to a mere rudiment, forming in man the coracoid process of the scapula (shoulder blade).

Origin of the Primates

8. From the primitive marsupials the most natural step is to some form of tree-living insectivore, — such a creature as the *Tupaia* or tree shrew of the Oriental Region. At about this stage the bats branched off, taking to the air and thus losing all chance of developing tool-making hands. From the primitive arboreal insectivore, somewhere about the beginning of the Tertiary age, we may derive the early Primates, more or less lemurlike forms. It may be worth while to ask why we have omitted all the other great groups of mammals from the possible line of descent. The answer is, that each one of them has specialized in a direction wholly divergent from a possible human stem. Thus the Rodents, in their teeth, and the Ungulates, in their feet, have gone to extremes which preclude the subsequent development of the human type of dentition or digital structure. Parts lost will not be regained, and parts extremely specialized and modified will not return to a relatively primitive condition.

Development of monkeys and man

9. From the long-nosed Primates, or lemurs, we may readily pass to the true monkeys and monkeylike forms. Here we come to a division, for although lemurlike animals were formerly spread over both hemispheres, the monkeys developed quite distinct types on the two sides of the world. Man, in his structure, is related to the Old World monkeys, not to those of South and Central America. Thus the traditional Old World origin of mankind is confirmed by zoölogical researches. No existing type of monkey can be said to resemble very

closely man's probable ancestor, each genus and species having developed along special lines since the time when the Hominidæ branched off. Man, as we have already noted, acquired an upright posture, going with a return to terrestrial life. His hands developed for the making and using of tools, and the brain to guide the hands. Yet for long ages, in spite of these advantages, man remained in a primitive condition, scarcely as prosperous as many of the animals prowling in the vicinity of his caves or shelters. Weak in many respects, his special endowments seemed to hardly more than make up for his failings and prevent him from perishing in the struggle for existence. It was not until many tens of centuries had passed that man assumed his dominant position as lord of the earth.

Recapitulation of stages of human evolution

10. To recapitulate, the principal stages in the evolution of the human type appear to have been: (1) Protozoan stage, (2) cœlenterate stage, (3) wormlike stage, (4) prevertebrate stage, (5) fish stage, (6) amphibian stage, (7) cynodont reptilian stage, (8) marsupial stage, (9) arboreal insectivorous stage, (10) lemurid stage, (11) monkeylike stage, (12) Hominidæ, or family including Homo, which is man. Perhaps some ingenious maker of moving pictures will one of these days project this evolution on the screen, so that in an hour the audience may see the protozoan develop by successive stages, to culminate in a human animal, disguised in the very latest fashions.

CHAPTER FIFTY-TWO

THE CHARACTERS OF HOMO

Man resembles the other vertebrates in structure

1. LINNÆUS, when giving names to all known animals, designated man as *Homo sapiens.* The generic name, *Homo*, is of course derived from the Latin. The specific term *sapiens*, from the same source, means "knowing" or "wise"; we use the word "sapient" in English. The genus *Homo* is placed in a family Hominidæ, which is only one of several families constituting the order Primates, of the class Mammalia. When we come to consider the characters of man, we find that they are mostly such as are also possessed by numerous animals. Thus the vertebral column is found in all vertebrates; the warm blood and hair on the body are common to Mammalia in general, to cat and dog, squirrel and mouse. On closer inspection we observe that the tissues of the body — the striated and unstriated muscle, the nerve tissue, the connective tissue, fat, cartilage, bone, epithelium, gland tissue, lymph, and blood — are all closely similar to those found in other vertebrates, and in many cases even in invertebrates. The organs or parts, made up of these tissues, — the eyes, nose, ears, heart, lungs, liver, etc., — all correspond to parts readily discernible in other mammals. So also the embryology, the order of development, is like that of other creatures. Certainly man does not represent an entirely new plan of creation, so far as his physical nature goes.

Special characters of man

2. Yet, in the midst of all these points of resemblance, we have no difficulty in observing differences; we recognize a human being at once. There are, indeed, more of these peculiarities than the non-anatomical person can discern. Here is a list of the more striking characters of *Homo:*

(*a*) The large brain, the cerebrum very large and much convoluted; that is to say, the apparatus

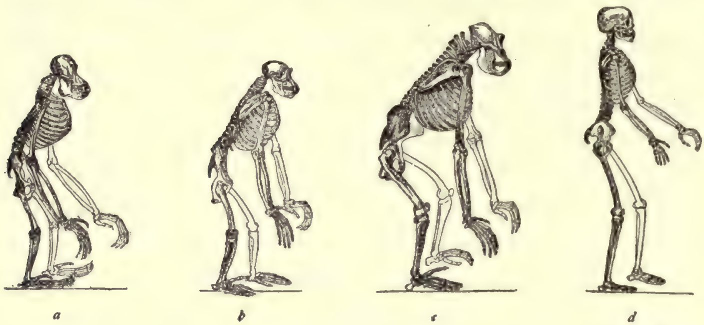


FIG. 201. Man and the higher apes: *a*, orang; *b*, chimpanzee; *c*, gorilla; *d*, man.

for receiving and storing impressions is very greatly developed.

(*b*) The face is shortened, so that the profile, at least in the higher types, is practically vertical.

(*c*) The lower jaw presents a distinct angle, the chin, at least in the best-developed races and individuals.

(*d*) The premaxilla, or anterior portion of the upper jaw, is not a separate bone, except at an early age.

(*e*) There is no distinct space (diastemma) between the incisor and canine teeth.

(*f*) The canine teeth are not appreciably larger than those next to them; that is, there are no distinct tusks.

(*g*) The spinal column has four curves, an adaptation to upright posture.

(*h*) The arms are not so long as the legs.

(*i*) A small bone, the os centrale, has disappeared from the carpus or wrist.

(*j*) The muscles of the thumb are better developed, giving free play to that member, and the index finger is freely movable independently of the others.

(*k*) The bones of the lower arm (radius and ulna) are so constructed that the arm may be rotated, as in turning a screw. This is of the utmost importance in connection with the use of tools.

(*l*) The leg and foot are adapted for walking, and the whole surface, from the ends of the phalanges to the base of the tarsus, is applied to the ground.

(*m*) The great toe is not freely movable, and is no longer readily used for grasping.

Other characters may be described as negative, being due to the loss of parts or functions:

(*n*) The tail is lost, being represented only by the coccygeal bones beneath the skin. This is, of course, not peculiar to man.

(*o*) The greater part of the hair has been lost from the body.

(*p*) Certain muscles of the head and neck have ceased to function, at least normally. Such are those which move the ear, and that which wrinkles the posterior part of the scalp. Some people, however, can use these muscles.

(*q*) The point of the ear is lost, being represented only by a small tubercle. On the other hand, the lobule has developed.

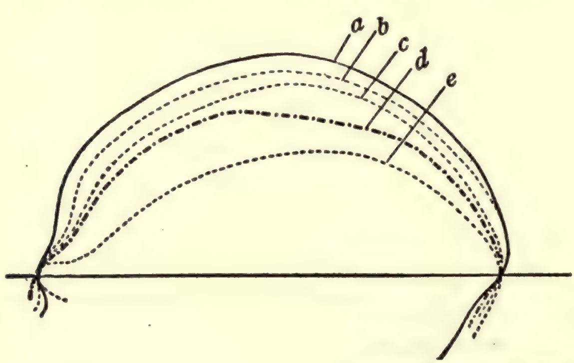
(*r*) There exists in the throat a small sinus or space which appears to represent the vestige of a howling sac, such as is so well developed in certain South American monkeys. The sac disappeared long before college yells were in-

vented; Nature could not anticipate a possible later function.

These characters are numerous, and others could be added, but it will readily be seen that from the standpoint of morphology they are quite unimportant in comparison with the resemblances. Many of them are not absolute or invariable. The great characters of man are mental; his brain, while similar in structure to that of his animal relatives, is capable of lifting him to a new plane of thought and action, whereby he stands apart from all other living things. A sufficient difference in degree becomes a difference in kind. Is man, then, isolated in his splendid powers? Is his a voice crying in the wilderness, with no possibility of an answer? It is the function of religion, rather than of science, to answer this insistent question.

Extinct relatives of man

3. Although the family Hominidæ at present includes only the genus *Homo*, there are indications of one or more other genera existing in former times. In 1894 the Dutch naturalist Dubois described the remains of an



From Keane's "Ethnology"

Fig. 202. Profiles of the crania of various manlike skulls: *a*, ordinary Irish skull; *b*, the Spy skull; *c*, the Neanderthal skull; *d*, *Pithecanthropus erectus*; *e*, skull of a gorilla.

animal which he discovered in the island of Java, and which seemed to possess the characters of the long-sought "missing link." He named it *Pithecanthropus erectus*, which means "the monkey-man walking erect." Only the upper part of the skull, a couple of teeth, and a femur or thigh bone were found. The structure of the latter was held to establish the erect attitude, but the skull showed very primitive characters. The brain must have been intermediate in size between that of the highest monkey and the lowest man. It is, perhaps, not absolutely certain that the thigh bone belonged to the same animal as the skull, and as the remains are very incomplete, we can only say that we have evidence of a type of Hominidæ so primitive that it may be regarded as constituting a distinct genus. The teeth are more like those of an orang than of a man, and it is possible that *Pithecanthropus* should be excluded from the Hominidæ altogether.

The Piltdown man

4. In 1913 Dr. A. Smith Woodward of the British Museum described the remains of a manlike creature found in gravel near Piltdown, Sussex, in the south of England. The fossils consisted of an imperfect skull and a mandible or lower jaw. The skull is very thick, but decidedly human in character, though relatively primitive. The jaw, on the other hand, is like that of a chimpanzee. This strange combination of characters led Dr. Woodward to regard the animal as a distinct genus of Hominidæ, to which he gave the name *Eoanthropus*, or "man of the dawn." More recently it has been maintained by able naturalists that two different things have been mixed together, and there is apparently little doubt that the jaw really belonged to an extinct species of chimpanzee, living at the same time as the man whose skull was found associated with it.

The Heidelberg man

5. The remaining fossil men or manlike animals have been referred to the genus *Homo*, but two extinct species have been recognized in Europe. The oldest of these, dating from the second interglacial period in the Pleistocene, is the Heidelberg man, *Homo heidelbergensis*, of Schoetensack. This species is known only by a massive and very peculiar jaw, without any distinct angle marking the chin. It was found in a sand pit at Mauer, near Heidelberg, in Germany, along with bones of the lion, extinct horse, rhinoceros, elephant, etc. As the oldest fossil *Homo* this specimen acquires the greatest significance, especially as it has very marked primitive characters, unquestionably indicating an extinct type of man. Roughly speaking, the Heidelberg man may be supposed to have lived about 250 thousand years ago.

The Neanderthal man

6. The other extinct *Homo*, living perhaps 50 to 100 thousand years ago, is the Neanderthal man, *Homo neanderthalensis*, of King. This rather unfortunately named being was widespread in Europe, and quite numerous remains have been found. The head was relatively large, but low-browed, and the brain was smaller than in modern man. The limbs were very robust and the shoulders broad, while the head and neck were bent forward rather than held erect. The knees appear to have been habitually bent, and the customary position when not in motion was presumably a squatting one. This powerful species of man, highly developed for the time in which he lived, was doubtless incapable of becoming civilized or of competing successfully with the true *Homo sapiens*.

7. Finally, we have abundant evidence in Europe of a race of cave dwellers, which, probably coming from the Orient, supplanted the Neanderthal man and took pos-

session of the country. This race, the Crô-Magnon, was veritable *Homo sapiens*. In his bodily structure, his skull, and presumably his brain, he was like modern Europeans. His lineal descendants are probably still living in France. For many thousands of years this race lived in caves, the walls of which it ornamented with remarkable drawings, sometimes in colors. Thus it is possible to look upon sketches of the hairy mammoth, made by men who hunted this now extinct animal. It is strange to contemplate the life of Crô-Magnon man, so primitive and barbarous, yet showing flashes of genius prophetic of the future. How could he know or imagine the forces latent within him, — his tremendous powers for good and evil, his capacity for invention and discovery? Could he have contemplated the future of his race, would he have rejoiced in the splendid coming developments, or would he have recoiled from the baseness and wickedness which he, the barbarian, could never have supposed possible? After all, we of today stand midway in the stream of human progress. Like the Crô-Magnon man, we are capable of much more than we know, and are destined to go forward to a future in the light of which the present will seem miserably inadequate. Unlike the Crô-Magnon man, we know that our feet are set on a path of progress, and that it is for us to decide where that path shall lead. Driven from our paradise of primitive simplicity, we have the choice of good and evil, but no longer the option of deciding whether to choose.

Beginnings of modern man, the true Homo sapiens

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CHAPTER FIFTY-THREE

THE GEOGRAPHICAL DISTRIBUTION OF LIFE

Environmental and historic factors

1. It is well known to all that the various forms of animal and plant life are not distributed uniformly over the earth's surface. When we seek to determine why the range of different species is limited, we find that the factors involved may be sorted out into two great groups, which may be termed the *environmental* and *historic*. The environmental factors are those which determine the possibility of existence in a given locality. Thus a fish cannot live on land; a tropical bird, transported to the arctic regions, would probably die in half an hour. These are the simplest cases, depending on physical conditions of the most obvious sort, but many other factors also must be classed as environmental. Thus the chestnut tree cannot exist in regions invaded by the chestnut-blight fungus; mice perish in the presence of a sufficient number of cats. In these examples the death-dealing causes may be directly observed, but many others escape our notice. Causes of death or failure to reproduce (which biologically comes to the same thing) frequently result in extermination only after a long period, and then the process is too slow to be conspicuous to the casual observer.

How the past affects the present

2. Historic factors have to do, not with the effects of the environment, but with the ability of the organism to reach given localities. The question is not, Can you live here? but, Were you able to get here? Humming birds would presumably flourish in tropical Asia and Africa, but they have never been able to cross the Atlantic or Pacific. Many European insects and weeds prosper exceedingly in America after being accidentally brought over by man, but in pre-Columbian times they

were all absent. We ourselves were excluded from America until navigation reached a certain stage of development. It is of course true that the so-called historic factors are also in a broad sense environmental; the restricting ocean, mountain, or desert is part of the environment. It is, however, the *peripheral environmental*, — the outer wall, not the medium in which the organism lives and has its being.

The multiplicity of causes and the interrelation of events

3. On further examination it appears that these broad distinctions, while useful, are very crude. We like to point out the "cause" of this or that, forgetting that life is subject to a vast multitude of "causes." Tennyson had this in mind when he wrote:

> Flower in the crannied wall,
> I pluck you out of the crannies,
> I hold you here, root and all, in my hand,
> Little flower — but if I could understand
> What you are, root and all, and all in all,
> I should know what God and man is.

It required the combined forces of the universe to produce the flower, and to ask *why* it was in the crannied wall is ultimately to raise more questions than any man can hope to answer. Nevertheless, we may by searching determine many things, and the study of geographical distribution leads us through winding paths to many remarkable conclusions.

Methods of biogeography

4. To illustrate the methods of biogeography, we may take any small area of ground on which plants are growing. We shall suppose that the plants found are the following: sunflower, dandelion, prickly-pear cactus, thistle, burdock, and snowberry. Determine the *species*, and then look up the known distribution of the *genera* and *species*. We find that they can be classified as follows:

(*a*) Genus exclusively Old World, except when spread by man: burdock.

(*b*) Genus native in America as well as Old World.

(1) Species native in America: thistle (if it is one of the American species, as will probably be the case).

(2) Species introduced into our region from Europe: dandelion.

(*c*) Genus and species native only in America: cactus; snowberry; sunflower.

So far, we are concerned with the historic factors. How did these plants come there? When a plant or animal is found native only in a given region, we say that it is *endemic;* so the cactus and snowberry are endemic in America. We may ask, however, whether it originated in the country where we now find it, or came from somewhere else. In the former case it is endemic in the strict sense, in the latter it may be called *precinctive*, if we wish to note the distinction. For example, the brightly colored snails of the Hawaiian Islands are certainly endemic; they are wholly different from those found elsewhere, and from their number and variety have evidently undergone considerable evolution on the islands. The redwood is now confined to California, but fossil redwoods are found in many other regions. There is no special reason for thinking that California, where the tree is making its last stand, was its original home. The distinction thus made is a real and interesting one, but very often we are unable to come to a definite decision. Even so, it may be worth while to try to estimate the probabilities.

Endemism

5. Having now discussed our plants from one point of view, we may take up the environmental factors. Perhaps there is a marsh or wet meadow not far away,

and in this none of our plants are found. As we go from one environment to another, we observe that our plants differ in their ability to exist in them, though there is no doubt that their seeds have reached these places. The dandelion is able to endure surroundings quite impossible for the sunflower. It also spreads more easily on account of its parachutelike fruits, and when once established lasts a long while, being a perennial. Thus we find ourselves discussing all the characters of the plants in their relation to the surroundings; the study of distribution becomes a broad study of dynamic botany, of forces rather than of mere structures. As in the other case, we find that precise answers to our questions are often impossible. They could be reached only through the knowledge of facts which we perhaps have neither time nor ability to ascertain. This must not prevent us from doing our best; the human mind must always face the unknown in the process of education.

Influence of environment, and the development of adaptations

From time to time we shall be rewarded by discoveries which will reveal the wonderful machinery of Nature. Thus it was found out that the spread of the Spanish bayonet or *Yucca* was strictly limited by the range of a little white moth which carries the pollen and brings about fertilization. Conversely, of course, the range of the moth is limited by that of the *Yucca*. These two partners have to go together; they cannot spread independently of each other. The Eastern United States, and particularly the Mississippi Valley, are remarkable for the great abundance and variety of large fresh-water clams. We know from fossils that similar shells were once more widely distributed, as they occur abundantly in certain deposits of the Rocky Mountain region. It might appear that they could live wherever there was

sufficient water, but it has been determined that many of them require the presence of certain kinds of fishes. They produce a larval form called the *glochidium*. The glochidia attach themselves to the gills of particular fishes, where they become covered or encysted (in the manner of a gall), and when at length sufficiently developed they break away and resume independent life. Thus the mussel *Lampsilis luteolus* requires the presence of basses or perches; *Oboraria ellipsis* is temporarily parasitic on the sturgeon. One species, *Hemilastena ambigua*, infests the gills of an amphibian, the *Necturus* or mud puppy.

Distribution indicates the geography of the past

6. The study of distribution may be made to throw much light on the past history of the earth. Thus, the marine fishes on the two sides of the Isthmus of Panama are so much alike that we are quite sure that the Isthmus was formerly submerged. This is now confirmed by the discovery of many fossil sea shells in the course of digging the canal. When islands, such as the British Isles, have a biota[1] nearly identical with that of the neighboring continent, we infer land connections in the past. Oceanic islands, which were never connected with any mainland, have only creatures of a type which might have crossed the sea. For example, they never have any truly native frogs, since these animals cannot endure salt water. When we are sure that two lands have formerly been united or separated, the degree of resemblance in the products is an index to the length of time which has elapsed since the change to present conditions occurred.

[1] Biota = fauna + flora; the total life of the country.

CHAPTER FIFTY-FOUR

THE BIOLOGICAL REGIONS OF THE WORLD

1. GEOGRAPHERS divide the land regions of the world into continents: Europe, Asia, Africa, North and South America, Australia. Biologists, investigating the distribution of life, long ago found that these divisions were unnatural, in the sense that they failed to agree with any definable life areas. For example, when we go from western Europe to northern Japan, crossing two continents, we find the plants and animals very similar throughout. Very many of the species differ at the extremes of this long area, but the general similarity is sufficient to impress even an unscientific traveler. On the other hand, if we pass from Tibet to the plains of India, all in Asia, we meet with an entirely new set of organisms. In America, the highlands of Mexico differ extremely in their products from the lowlands along the coast, the *tierra caliente* or hot country.

The continental areas of geographers do not correspond with life areas

2. In 1857 an English naturalist, P. L. Sclater, made a detailed study of the distribution of birds, and came to the conclusion that it was possible to define a series of great zoölogical regions, each of which would be found to possess a fairly similar fauna throughout. Sclater's regions were studied by A. R. Wallace, who found that they were equally valid for practically all groups of land animals. Later investigations showed that they applied to plants also. These regions are so "natural," — that is to say, so recognizable by their products, — that any competent zoölogist or botanist, transported blindfolded to a point within one of them, could tell which it was after half an hour's investigation. Difficulty would be likely to arise only in places on or near the boundary of two regions.

The biological regions of Sclater and Wallace

Definition of the biological regions

3. The Sclater-Wallace regions are named and defined as follows:

(*a*) *Nearctic*, or northern region of the New World. North America, excluding all tropical portions except the southern end of Florida.

(*b*) *Neotropical.* South America, and all tropical parts of Mexico and Central America, as well as the West Indies.

(*c*) *Palæarctic*, or northern region of the Old World. Europe, Africa north of the Sahara Desert, and the temperate parts of Asia.

(*d*) *Ethiopian.* All Africa except the northern temperate portion.

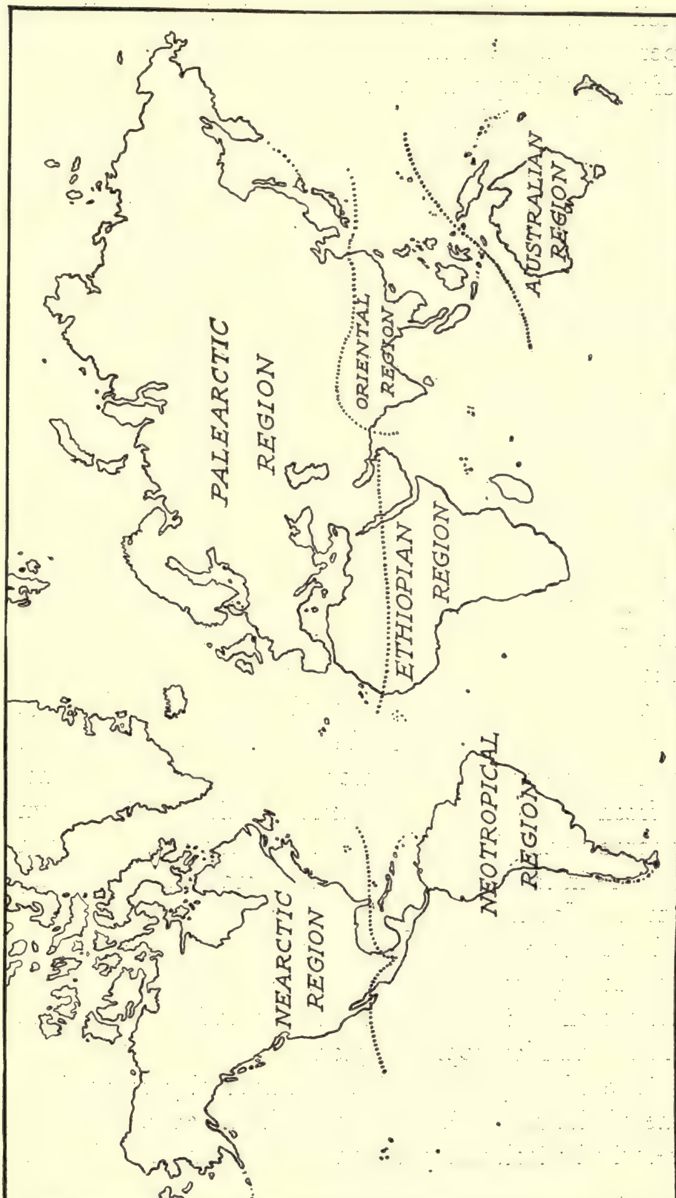
(*e*) *Oriental.* Tropical Asia (Indian Region of Sclater).

(*f*) *Australian.* Australia, New Guinea, and adjacent islands.

Oceanic islands

The *Oceanic islands*, such as the Hawaiian Islands, cannot properly be attached to any of the great regions. The *Antarctic continent* also is to be considered separately, but it has very little terrestrial life at the present time, though it is known to have been warm and fertile in remote geological periods. It is especially distinguished today by the penguins, a very ancient type of birds existing in great numbers along the coast (see page 380).

It is possible to criticize the names given to some of the regions, but they are so well established that they cannot now be altered. From a scientific point of view, of course, the two sides of the world are not "new" and "old"; and, on the other hand, the popular use of the word "arctic" is for far northern, not temperate, regions. The original meaning of "arctic" was simply northern, — the region where the "arctos," or



Drawing by W. P. Hay

FIG. 293. The biological regions of the world according to Sclater and Wallace.

constellation of the Great Bear, which we call the Dipper, may be seen in the sky. Sclater's use of it is, therefore, philologically correct.

Holarctic region

4. The proposal has been made to combine the *Nearctic* and *Palæarctic* regions, making a single immense *Holarctic Region*. It is true that the northern regions of the two hemispheres have in many respects similar products, and when we go far north, or examine the summits of the higher mountains, we find a *circumpolar biota*, with identical species on the two sides of the world. Nevertheless, there are very marked differences, which justify the separation of the Nearctic from the Palæarctic. Thus, for example, the numerous North American mice and related animals mostly represent genera distinct from those of the Old World. In America we find skunks, raccoons, the pronghorn antelope, the mountain goat, the prairie dogs, the opossum, and many other animals quite distinct from those of Europe and Asia. So also we observe many distinctive birds, from the turkey to the humming bird, the mocking bird, and the turkey buzzard, the snowbird and the vireos, a multitude of warblers, etc., etc. Similar differences exist among reptiles, amphibians, and fresh-water fishes. Recent studies have shown that some of the fishes supposed to belong to European genera are in fact quite different. Among the flowering plants the North American flora is rich in special types, found nowhere else in the world. There are also numerous genera of plants, such as the sunflowers, which are exclusively American, but occur in both the Nearctic and Neotropical regions.

The circumpolar biota

Distinctions between Nearctic and Palæarctic regions

Neotropical Region

5. The *Neotropical Region* is universally recognized as one of the most distinct, as might be expected from its relatively isolated position. Its animals include a

special group of monkeys with prehensile tails, llamas (which are related to the camels), sloths, armadillos, anteaters, guinea pigs or cavies, the chinchilla, the capybara, and many others. Humming birds are extremely numerous, and Wallace says: "There is no other continent or region that can produce such an assemblage of remarkable and perfectly distinct groups of birds; and no less wonderful is its richness in species, since these fully equal, if they do not surpass, those of the two great tropical regions of the Eastern Hemisphere combined."

Palæarctic Region

6. The *Palæarctic Region* shows resemblances to the Oriental, just as the Nearctic does to the Neotropical. It is, however, a purely temperate region, in most respects contrasting strongly with the tropical areas to the south. Among its characteristic animals may be enumerated the hedgehog, dormouse, chamois, and a number of peculiar mice. The birds include a long and varied series belonging to the thrush family, many larks and starlings, pheasants and their relatives, etc. There are numerous special types of amphibians, including newts and salamanders, frogs and toads.

Ethiopian Region

7. The *Ethiopian Region* is remarkable for the number of large animals, such as the African elephant, hippopotamus, giraffe, okapi, zebra, many genera of antelopes, gorilla, chimpanzee, etc. Among the birds we think first of the ostrich. Madagascar is included in the Ethiopian Region, but its biota is peculiar — so much so that some have wished to set it apart by itself. It lacks the characteristic large animals of the African mainland, and has a great variety of lemurs, strange animals related to the monkeys but relatively primitive.

Oriental Region

8. The *Oriental Region* is most nearly related to the Ethiopian. Its most characteristic creatures are the

Indian elephant, tiger, orang-utan, peacock, various hornbills, etc. From this region comes the original type of the domestic fowl. The desert parts of northwestern India have an essentially Palæarctic fauna, continuous with that of Persia. The limits of the Oriental in the direction of Australia have been much discussed, but it is universally agreed that the Philippines, Borneo, and Java are to be included; while New Guinea, with its birds of paradise, is classed with the Australian Region.

Australian Region

9. The *Australian Region* is the most peculiar and isolated, and its three principal parts, Australia, New Zealand, and New Guinea, differ radically among themselves. The mammals are mainly marsupials, a very primitive group including the kangaroo and a variety of other types of diverse habits and appearance, one even having the appearance and mode of life of a mole. The egg-laying mammals (monotremes), including the duckbill and echidna, are even more archaic than the marsupials. Among the birds are the emeu, cockatoo, and many others of remarkable appearance and habits. The plants include the eucalpytus trees, now so widely planted in California and elsewhere.

New Zealand

New Zealand lacks all the characteristic Australian mammals, etc., but possessed very recently the extraordinary giant birds known as *Dinornis*, and still has the much smaller kiwis (*Apteryx*). These birds are wingless, and could hardly exist in a country where there were many predatory animals. The species of *Dinornis*, or moa, were hunted by the Maoris or native people of New Zealand, but were exterminated before the arrival of the white man. The peculiarity of New Zealand is further emphasized by the existence of a remarkable lizardlike reptile (*Sphenodon*), constituting an order not found elsewhere.

Distribution of animals and plants in past ages

10. The biological regions, as defined above, have not always been separated as we find them today. The study of fossils shows that in former geological epochs the climates of various parts of the world were very different from those now found, while both animals and plants have migrated freely. For example, the marsupials, now characteristic of Australia, were once common over the greater part of the world. The American opossum, a true marsupial, is a relic of this once wide distribution of the group. The camel family was once abundant in North America. The redwood tree, now native only in California, was formerly widespread. Thus the biological regions, as we now understand them, are valid only for the present epoch; when we go back to earlier times they must be redefined and limited in quite other ways. Naturally our information concerning the past is not nearly so complete as that for the present, hence the limitations of former regions cannot be exactly stated.

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CHAPTER FIFTY-FIVE

LIFE ZONES

The life zones of North America

1. EVERY one knows that there are in North America very different regions, producing special kinds of plants and animals. Not only do the native or wild products of these regions differ, but of course also the crops and conditions affecting human life. Thus we have the corn belt and the cotton belt, the wheat country and the grazing country, etc. Many years ago Dr. C. H. Merriam, then of the United States Department of Agriculture, undertook to make a careful study of this subject, in order to determine general principles or laws which might be of scientific and practical value. He found out that, broadly speaking, the whole country could be divided into a number of belts or zones, which he called life zones, each distinguished by its fauna and flora. This was not in itself a new idea, but it had never before been worked out in detail, with such a mass of data. The several zones did not, of course, differ entirely in their products; but when the observer took note of a number of different plants or animals in any locality, he usually had little difficulty in determining its zonal position. Sometimes the transition was quite abrupt, as for instance at the limit of trees in the north or on mountains, and less conspicuously in the limitation northward of tropical plants which cannot endure frost.

Isotherms

2. These zones owe their biological differences almost entirely to climate. From south to north, and from lower to higher altitudes, the climate becomes colder. The *isotherms* are lines running across the country, marking the same temperature for the year or any particular part of it. It seems at first very simple

to define the zones by these isotherms, but the matter is actually much more complicated. In the first place, *temperature* is not the only factor; *moisture* is exceedingly important. The desert and forest may have the same mean annual temperature, may be on the same *isotherm*, yet they differ entirely in their life, perhaps hardly possessing a single species in common. Then again, it makes a great deal of difference when the moisture falls, and when the cold and warm weather occur. Dr. Merriam laid special emphasis on the total amount of heat received during the growing season of plants, and on the other hand the minimum winter temperature is a decisive factor for many kinds. Even the variations between day and night are very important. Thus in cloudy localities the temperature in the spring may differ comparatively little during the twenty-four hours; but in the arid Southwest, where the skies are clear, the rapid loss of heat at night may give rise to killing frosts, following uncomfortably warm days. The amount of evaporation is a factor which cannot be ignored, and it depends upon the moisture in the atmosphere and the movement of the air, as well as on the actual temperature. Finally, in some places we find what is called *inversion of temperature*, the tops of the hills or sides of the valleys being actually warmer than the lowlands. In such a locality as Salt River Valley, Arizona, this is due to the fact that cold air is heavier than warm, and so sinks, displacing the warmer air much as water would. Growers of oranges know that the sides of the valley are less liable to injurious frosts, and the value of land is affected by these considerations. In the vicinity of San Francisco, California, the same general result is brought about by the sea fogs. Thus the summit of

Inversion of temperature

Mount Tamalpais is drier and warmer than the Muir Woods immediately below, and the normal relationship of the zones is reversed.

Practical value of study of life zones

3. From the above considerations it may well appear that the whole subject is so complex as to make the definition of zones impossible. We are, indeed, warned against a too rigid application of Dr. Merriam's principles; but the experience of years has shown that the life-zone theory is not only essentially sound, but of very great practical importance. Nature has been experimenting for ages past; her records are far more complete than those of the meteorologists, and she has determined by severe processes of selection what life may exist in each locality. Consequently, if we study the native biota, — that is, the wild life of a region, — and determine that it exists under a given set of conditions, then the appearance elsewhere of the same biota comes to be an indicator of climate. Such an indicator does not take account of single factors alone, such as temperature, but includes everything which is significant. Reasoning in such ways, we are able broadly to indicate in advance what crops will be likely to succeed in new localities, — something of peculiar importance in a country like ours, where agriculture and horticulture are continually extending their boundaries.

The zones defined

4. The life zones in North America may be defined as follows, beginning with the northernmost:

Boreal

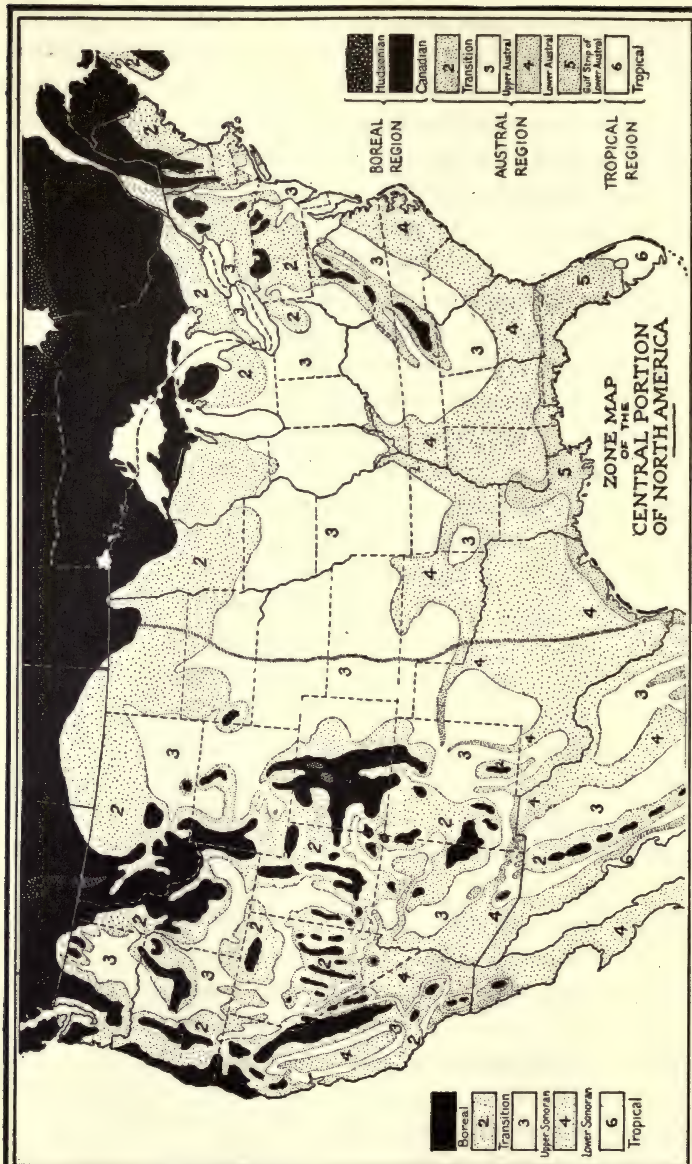
A. Boreal (*borealis*, northern). This may be divided into three zones, as follows:

(*a*) *Arctic-alpine Zone*. In the arctic regions, beyond the limit of trees, and on mountains above timber line. The arctic and alpine parts differ in one important particular. Arctic regions

have continuous though not intense light in summer, and a long winter night; but alpine summits are lighted by day and dark by night, as are the lowlands. Alpine heights are distinguished by the extreme beauty and great abundance of the flowers, which are large in proportion to the often mosslike plants which bear them. The fauna includes such animals as the mountain sheep and the ptarmigan, — the latter a grouselike bird which turns white in the winter, the color of the snow which everywhere surrounds it.

(*b*) *Hudsonian Zone.* So called because it is well developed in the vicinity of Hudson Bay. It is a zone of dense coniferous forests, with here and there a flowery meadow. In the west it is of importance as the recipient and conservator of the moisture which ultimately finds its way into the streams and irrigates the varied crops of the plains. The soil, largely composed of vegetable débris, and sheltered from the rays of the sun, acts as a sponge and provides for a continual stream flow instead of roaring but transitory torrents.

(*c*) *Canadian Zone.* A zone of mixed vegetation, with aspens, various conifers, and small fruits such as blackberries, raspberries, and cranberries. This is the first zone in which we find crops, unless timber is regarded as a crop. The potato, timothy grass, and some of the more hardy cereals are regularly grown. The glades and meadows are filled with tall and luxuriant herbaceous plants, of the type of vegetation known as *mesophytic*, — that is,



Redrawn by W. P. Hay from Am. Ornithologist's Check List of N. A. Birds

FIG. 204. (For description see note at foot of page 459.)

"middle plants," of neither very wet nor very dry ground.

B. TRANSITION. This is the most difficult to define, because it is in fact a meeting place of the boreal and austral (southern) elements. Here will be found biological *tension lines*, where northern and southern, mountain and plain, organisms press outward from their center of distribution, and meet one another. The Transition may be divided into three areas: **Transition**

(*a*) *Alleghanian Area*. The humid Transition of the country east of the hundredth meridian. It is especially prominent in Minnesota, Wisconsin, Michigan, New York, Pennsylvania, Ontario, New England, and the Alleghany region. It is a region of mixed forests: chestnut, walnut, oak, beech, maple, etc. The deciduous fruit trees are highly successful: apples, pears, plums, etc. It is a region of hops and potatoes also.

(*b*) *Coloradian or Arid Transition Area*. This occupies large parts of Colorado, Utah, New Mexico, Wyoming, Nevada, and the Northwest, and is for the greater part rather barren when not irrigated. It is characterized especially by the yellow pine and the so-called sagebrush (*Artemisia*). Under irrigation it

NOTE ON ZONE MAP. The Arctic or Arctic-alpine Zone, extending northward beyond the limit of trees and on mountains above timber line, is not shown on the map, nor are the subdivisions of the Transition Zone and the Sonoran Area.

The diagonally shaded line marks the eastern border of the Great Plains and divides the Austral Region into an eastern, more humid portion and a western, more arid portion. East of the line the divisions are known respectively as the Alleghanian, Carolinian, and Austroriparian Areas. The western portions of the same Zones are known as the Transition, Upper Sonoran, and Lower Sonoran Areas. The Middle Sonoran is not distinguished from the Lower Sonoran on the map.

produces abundant crops, both fruits and cereals, and also sugar beets.

(*c*) *Columbian or Humid Northwestern Area.* In the extreme northwestern part of the United States and adjacent parts of British Columbia, along the coast, the climate is excessively humid. In places the annual rainfall amounts to 100 inches. The forests are most luxuriant, and the country is full of life. The temperature is much more uniform than that of the Coloradian, and there is less sunshine. Many fruit trees do well, and roses and other flowers grow to perfection.

Upper Austral

C. Upper Austral.

(*a*) East of the Hundredth Meridian.

(1) *Carolinian Area.* Here the traveler from the north first meets with the sassafras, tulip tree, hackberry, and persimmon. It is the great *corn belt*, and is in every way of prime agricultural and horticultural importance. One may travel in it through the states of Ohio, Indiana, Illinois, Missouri, and Kansas, reaching the limit in western Kansas.

(*b*) West of the Hundredth Meridian.

(2) *Upper Sonoran Zone.* The western zone corresponding to the Carolinian, but very different on account of the arid climate. It is nearly all open country, with comparatively scanty vegetation. Under irrigation it is very prolific, and one may see luxuriant orchards and fields, separated only by a wire fence from desert or semi-desert. The word "Sonoran" is derived from Sonora, a Mexican state.

(3) *Middle Sonoran Zone.* This combines the crops of the Upper Sonoran with many of the wild plants and animals of the lower Sonoran. It is subject to severe frosts in winter and spring, rendering it quite unsuited to the orange, olive, and other Lower Sonoran fruit trees. The native trees and shrubby plants delay coming into leaf and flower, notwithstanding the warm days, and so escape injury. The cultivated plants, coming from other regions, have not developed this peculiarity. Southern New Mexico is typical of this zone.

D. LOWER AUSTRAL. **Lower Austral**

(*a*) East of the Hundredth Meridian.

(1) *Austro-riparian Area.* This is the *cotton belt*, occupying most of the Southern states. From it may be separated the following:

(2) *Semitropical or Gulf Strip.* Along the coast from Texas to Florida; the region of the palmetto and the sugar cane.

(*b*) West of the Hundredth Meridian.

(3) *Lower Sonoran Zone.* The desert region of the extreme Southwest, characterized by mesquite, cactus, yucca, and many other peculiar plants, as well as a remarkable set of animals. There is a flora of "winter annuals," appearing in late winter and early spring, and rapidly going to seed. The cultivated trees, of course irrigated, include the date palm, orange, olive, walnut, peach, etc. **Tropical**

E. Tropical. The region without frost at any time of year. It reaches the mainland of the United States only at the southern extremity of Florida. Parts of southern Arizona and California, in the valley of the Colorado River, have a mean annual temperature which would entitle them to be considered tropical, but they must be excluded, as they have winter frosts. The most characteristic plant of the tropics is, perhaps, the coconut palm, which fringes tropical shores all round the world.

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Cyclopedia of American Agriculture, Vol. I (1907), page 20. For details concerning the distribution of life in North America see especially the Bulletins of the Biological Survey, United States Department of Agriculture, Washington, D. C.

CHAPTER FIFTY-SIX

LIFE IN THE TROPICS

The tropical forest

1. WITHIN the tropical zone are many different climates. The humid forest contrasts with the grassy uplands or mountain peaks, and the desert with both. It is in the dense forest that we think of tropical life as being most typically developed, and here it is that conditions are most strikingly different from those of the temperate zones. In such a forest we note at once the immense size of the trees, and their closeness to one another. Where the forest is thickest it may be perpetual twilight on the ground. Then we observe that the herbaceous plants so characteristic of sylvan spots in the north are almost or quite wanting under the trees. In any enumeration of a tropical flora, the ground-living small plants are relatively few, and the number of species of trees is astonishing. There are, however, many woody climbing plants, and high up in the trees one perceives the epiphytes, plants which live on the trunks and limbs, never reaching the ground below. Many of these latter are orchids, some of them with magnificent flowers. Yet the general impression gained is that of greenness, without much color. The bright flowers are dotted here and there, often so far aloft that they cannot be seen. There is nothing like the gay carpet of color to be seen any spring in a European or American glade, or on the summits of high mountains during the short summer season.

Diversity of plants in the tropics

2. In temperate regions it is common to find forests consisting mainly of one kind of tree — pine or oak, beech or chestnut. In the tropics there is amazing diversity, and when a specimen of a particular tree has

been found, it may be necessary to go half a mile to find another. A Dutch botanist records finding 600 species of arborescent plants in an area of about $1\frac{1}{8}$ square miles in the Malay Archipelago. When Professor Beccari was building a small house in the Bornean forest, he found three small trees in such a position as to be exactly suitable for corner posts. So he cut off the tops, and secured a fourth post for the remaining corner. On looking at the tops he had removed, he found that his three trees were all of different genera and all represented species new to science. It will readily be understood that under the conditions described the "struggle for existence" is extreme. Each plant produces a multitude of seeds, but few of these ever grow into mature plants. The two most necessary things are room and light. There is no space for new trees until the old ones die. Then they are rapidly destroyed by insects, fungi, and bacteria, and there is a scramble to secure the open space. Epiphytes, living far aloft, may secure access to light which they could not have lower down. Certain trees of the fig group, called "malo palo" or bad tree in Guatemala, by means of their great aërial roots surround great trunks in the forest and eventually strangle and destroy their victims, — trees of other species, — in order to take their place.

The animal life of the tropics

3. Such luxuriance and variety of vegetation makes possible a corresponding variety of animal life. Insects, in particular, are extremely numerous and varied. All those creatures which feed on vegetation become adapted to particular kinds of trees and other plants. Thus a given tree will have its special fauna, feeding on the roots, trunk, branches, leaves, or visiting the flowers. The creepers which ascend the trunk will

likewise support a series of small creatures; so also the epiphytic orchids and Tillandsias. Thus a single tree, with its accompanying smaller plants, supports a great population of insects, snails, centipedes, etc. When the trees are so varied, it will readily be understood that the fauna must be enormous. A Colorado high school teacher, a few years ago, secured a leave of absence from her school to visit Guatemala. She was away six weeks, two of which were occupied by the journeys, coming and going. In the month she had in the country she was able to discover 78 species and varieties new to science, including a large and beautiful tree, a snail, several protozoa, and a great number of insects.

Tropical species usually well defined

4. One might suppose that the study of tropical life, owing to its variety and complexity, would be extremely difficult. It is anything but easy, but the naturalist who has struggled with the poorly defined species of temperate regions turns with relief to the tropical biota, where the different forms commonly possess recognizable or even conspicuous characteristics. In the tropics it appears that conditions must have remained substantially the same during long ages, while the intense struggle for existence has hewed, as it were, each species very closely to the line of optimum efficiency. Thus characters have become stereotyped, species fit exactly into their niche in the architecture of nature, and general variability is likely to be suppressed. In temperate regions we are recovering from the last glacial period, species are still plastic and in the making, at least in many genera, and it is difficult to define them exactly, for the reason that Nature has not done it. In large collections from the tropics, for example of wild bees, it often appears that

certain species are extremely variable; but on closer examination this seems to be illusory. There are, in fact, very numerous allied species, each occupying its own area and uniform within it.

Special faunas

5. Certain parts of the tropics are famous for the abundance of particular groups of creatures, as all collectors know. Thus for snails we go especially to the Philippine Islands, the Hawaiian Islands, Cuba, or Jamaica; for ferns, to Jamaica. Butterflies are excessively numerous in South America. If we care for rats, the Malay Archipelago will supply almost unlimited numbers of species. In general, continental areas are much richer in species than are islands, if we except certain groups. There is no part of the tropics which will not reward an industrious collector with numerous novelties, and many generations of men must pass before the biota of the richest regions of the world is adequately catalogued. The best treatment of a single tropical area is found in the series of volumes on the *Fauna of British India*, published by the British Government, but this is still very incomplete. The *Biologia Centrali-Americana* is a great work on the animals and plants of Mexico and Central America, — a splendid contribution to science, but very costly, and enumerating only a fraction of the life really existing there.

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CHAPTER FIFTY-SEVEN

LIFE IN THE ARCTIC AND ANTARCTIC REGIONS[1]

1. THE frozen north, and the still more frozen south, are in most respects ill-suited for the development of terrestrial life; yet they are of special interest to the biologist. In the moist tropics, where life is most abundant, it is its own chief enemy. Plant struggles with plant, animal with animal, animal and plant together. In the arctic, as in the desert, the principal struggle is with the environment. There is generally room enough, but how to endure the climate, to survive under such hard conditions, is the real problem. Nature, however, makes the most of every opening, and develops types which are so well adapted to seemingly adverse conditions that they cannot get along without them. Thus the polar bear, accustomed to a world of ice, looks hot and miserable in the London Zoölogical Gardens, during the very temperate English summer.

The struggle with the environment

Adaptation to cold regions

2. The north polar regions are radically different from the south, in that the north pole is covered by a frozen sea, whereas the south is in the middle of a great area of elevated land. We might at first imagine that land would be more favorable to animal life than sea, but this is not the case. The sea, even in the extreme north and south, is full of animal life, — whales, fishes, and invertebrates. The fishes may feed on minute crustacea or worms, the seals on fishes, the polar bears on seals. Aquatic plants, mostly of minute size, serve as food for the smaller animals. Thus the sea is a source of food for so-called terrestrial animals, which may live mainly upon the ice. In

Life in the south polar region

[1] The word "arctic" comes from *arctos*, Greek for "bear." Hence the careless spelling "artic," a prevalent vice of students and others, is especially to be condemned.

the midst of the antarctic continent there is no such source of food, and consequently life is practically confined to areas near the coast. Were the temperature of the whole earth to fall to that of the polar regions, life would persist in the oceans and along the coasts of the continents, but the interior uplands would be barren and desolate.

Microscopic life in the north

3. Nansen tells us how he found the arctic ice teeming with thousands of millions of microscopic organisms. The sun melts the snow, forming pools on the ice, and these soon show yellowish-brown spots, at first small, but gradually increasing in size. These, under the microscope, are seen to consist of minute plants, principally diatoms. Each spot represents an enormous population, a little city of these simple organisms. Also present, feeding on the plants, are many different kinds of protozoa. Thus the frozen north, apparently so barren, is really full of life, — life which prospers and finds no hardship in the conditions which exist. Under the ice, in the sea, are many other creatures.

Vertebrate animals of the north

4. The higher, more conspicuous life of the north is much better known. Every one has heard of the polar bear, the walrus, the arctic fox, and the musk ox of Greenland. So also there are many birds, some of them common visitors to more southern regions in the winter. The beautiful Ross's gull, with rosy breast, is called by Nansen a "rare and mysterious inhabitant of the unknown north, only occasionally seen, and no one knows whence it cometh or whither it goeth." Some of the arctic animals are white, like their surroundings, others quite the reverse. To be white is to escape observation, as when the polar bear creeps soft-footed toward the seal; but the musk oxen, living in herds,

and quite well able to take care of themselves, would gain little from inconspicuousness. Indeed, it is doubtless an advantage, if an animal chances to get lost, that it can easily see and be seen by its fellows.

5. In Siberia and Alaska there is a profusion of insect life in the summer, especially of mosquitoes. All travelers in these regions agree in describing the clouds of mosquitoes, which make it necessary to wear a veil, and render life almost unendurable at times. Wallace points out that no less than 173 species of birds breed in the arctic regions, and that a principal source of food for the young must be these insects, which thus become a very important factor in supporting a large number of valuable and interesting birds. Also, the arctic tundra is gay in summer with beautiful flowers, and many wild fruits exist, affording further nourishment to the hosts of birds. These things, of course, are found only on the land areas, and only where the summer temperature is high enough to stimulate growth. There is nothing of the kind in the south polar lands, which support only very simple organisms, aside from those living in the sea or getting their living out of the sea.

Arctic insects and flowers

6. Although the south polar region has no bears, foxes, or musk oxen, there are plenty of seals. There are also penguins in great numbers. In the account of Scott's expedition these birds are described at length, with illustrations from photographs. In 1911 several members of Scott's party made an extremely difficult and hazardous journey to secure the eggs of the Emperor Penguin. They were away from the main camp from June 27 to August 1, which is the middle of the antarctic winter. They found the birds sitting on their eggs in a temperature 20 to 30 degrees below

Southern vertebrates

zero, and secured the specimens necessary for the study of the early stages. This was particularly important, since the Emperor Penguin is perhaps the most primitive of all living birds. That any species of bird should reproduce in the middle of the long winter night, with the temperature far below zero, would seem incredible were it not proved by the most reliable testimony. The species of penguins occupy the shores of far southern lands, and find their food in the sea.

Resemblances between the arctic and antarctic biota

7. Arctic and antarctic life differ very conspicuously, especially as regards the larger animals. When we come to the smaller forms, and especially those found in the sea, there are many resemblances which have caused surprise. Separated by a broad tropical zone, it would not seem likely that any species could pass from one polar region to the other. Hence it has been suggested that perhaps the similarity might be due merely to the likeness of the environment, causing similar forms to develop independently. It has been remarked, however, that even under the equator the depths of the sea are cold, and currents flowing along the ocean floor might carry cold-water organisms right across the tropical belt.

Former warm climates in the polar regions

8. At one time, or indeed at more than one time, in the past, the arctic and antarctic regions were relatively warm and supported luxuriant vegetation. This is shown by the numerous fossil plants found in Greenland and Spitzbergen, and by the remains more recently collected in Antarctica. On the return from the south pole, Dr. Edward A. Wilson found fossil plants far in the interior, and the party, with the greatest pluck, dragged the specimens, under almost incredible difficulties, to the camp where they finally perished. The

specimens were found with the bodies of the explorers, and serve to prove that even this frigid country once enjoyed a mild climate.

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CHAPTER FIFTY-EIGHT

LIFE IN THE SEA

The sea the great mother of life

1. THE sea occupies the greater part of the world's surface, and teems with varied forms of life. The oldest known fossils appear to be exclusively marine, but these have gone far along the path of evolution. The beginnings of life were certainly associated with water, but they may have been in the soil, which is still occupied by a great variety of organisms scarcely known even to naturalists. However this may have been, the sea is nevertheless the great mother of life, the source of many great groups, some of which have emerged from the waters to occupy the land. The reverse process, the adaptation of land groups to marine existence, is much less common. The whales and porpoises are mammals, certainly with terrestrial ancestors. A few species of mollusks, living near the shore, show characters indicating their relationship to land snails. Some true snakes, not the sea serpents of fable, are sea dwellers. There are hemipterous insects which skim the surface of the open ocean, but are related to inland forms. All such instances, taken together, are relatively few, whereas the whole arthropod phylum, for example, appears to have first developed in the sea.

Marine and terrestrial life contrasted

2. There is, however, the strongest contrast between the character and evolution of marine and terrestrial life. In particular, the plant and animal kingdoms occupy very different relative positions. At first sight it might well appear that the sea is the home of animals, the land of plants. Plant life in the sea consists almost wholly of lowly forms, — sometimes gigantic, as the kelp of the Pacific coast, but flowerless and anything

but highly organized. Such an exception as the *Zostera*, which really has minute flowers, obviously represents a modified form of inland ancestry. Closer examination shows that the conspicuous seaweeds are confined to the coast belt and certain areas where floating species exist. The greater part of the ocean is without noticeable plant life, though the upper layers are full of minute diatoms and other equally inconspicuous though by no means insignificant types. The sunless depths have no plants at all. Every part of the sea, on the other hand, supports animal life. It abounds in the far north and south, where land life is scarce. It exists in the abyssal depths, which occupy nearly half the earth's surface. It includes great numbers of groups, such as the starfishes, crinoids, and lamp shells, which have no terrestrial or even fresh-water analogues. In the past it was the same. The rocks, dating back millions of years, are full of marine shells, echinoderms, fishes, and the rest, but we rarely find recognizable plants in sea deposits.

The land, on the other hand, is often covered with forests. The higher plants are all terrestrial. Animal life on land, in spite of its high development, seems almost secondary to the flora. Only in towns do the animals (principally *Homo sapiens*) appear to exceed the plants. Rocks formed inland often contain plant remains in great variety, without a single animal.

The littoral zone

3. Looking out upon the ocean, we get the impression of extraordinary uniformity. North, south, east, and west, wherever the sea extends, we find a waste of waters, — without mountains, without valleys, without forests or rivers. It is only after close study that we appreciate the erroneousness of this superficial view. There are currents in the sea, flowing like

rivers; the most famous is the Gulf Stream. The surface conditions are very different from those below, and the coasts are unlike deep waters. The zone along the coasts, known as the *littoral zone*, is narrow, sometimes very narrow. It may be defined as that area in which a considerable amount of light penetrates to the bottom. There is the region between the highest and lowest tide marks, and a variable extension beyond the level of the lowest tide, until we reach really deep water. Here the large red and brown seaweeds grow in abundance, and animals are often brightly colored. Here, in the tropics, are the coral reefs. Organisms belonging properly to the littoral zone are confined to singularly narrow limits, as if in a gigantic river. Most of the long coast lines extend north and south, and consequently the littoral fauna is blocked in its migrations north and south by climatic changes. These changes may be quite abrupt, owing to the meeting of warm and cold currents; thus the faunas north and south of Cape Cod and, on the Pacific coast, of Point Concepcion are markedly different. This confinement to a relatively narrow area makes the species of marine animals more local in their distribution than we might at first expect. In many cases, however, the animals have free-swimming early stages, which are carried out to sea by the currents, and may reach remote islands or other continents. Of such larvæ, setting out for the unknown, nearly all perish, but a few survive and establish their kind on other shores. Nature, as the poet said, is careless of the single life, but careful of the race.

The plankton

4. The floating organisms of the open sea, or even of the surface layers of a lake, are known collectively as the *plankton*. Properly speaking, the plankton in-

cludes those creatures which are more or less passively carried by the movement of the water, and are not far from the surface. At first sight it might seem that such forms were few and of little interest. From the deck of a vessel one sees an occasional jellyfish, fragment of seaweed, or, if fortunate, a "Portuguese man-o'-war" (*Physalia*). Better indications of the abundance of the plankton are obtained at night, when the wake of the ship glows with the phosphorescent light of small organisms. If, however, the fine-meshed plankton net is used, dragged not too rapidly along in the surface waters, it is found to contain a whole population of animals and microscopic plants. These, on being sorted out, are found to belong to many different phyla, classes, orders, and families. Some are very young forms of littoral or bottom species, others are permanent inhabitants of the plankton layers. Many are transparent, or delicately tinted with blue, so as to be almost invisible, though of fair size.

The nekton

5. At various levels between the surface and the bed of the ocean will be found a number of free-swimming animals, mostly fishes. These are collectively known as the *nekton*. Unlike the typical plankton, they move freely through the water, and are not drifted hither and thither by the currents and tides. Much of this nekton fauna is hard to catch, and our knowledge of it is correspondingly imperfect. We know, however, that there are great diurnal and seasonal migrations of many species, so that they may appear near the surface at certain hours, and at others be far below; or they may travel from one locality to another. These movements are of the greatest importance for the fishing industry, and in Europe an international organization was investigating these and other prac-

tical problems with great success, until the war put a stop to the coöperative plans. In the efforts to trace the migrations of fishes, very elaborate methods have been devised. Thus it has been possible to learn much about the mackerel and herring by carefully measuring thousands of individuals, in order to distinguish the slightly different races. Also, especially in the case of the salmon, the seasonal markings on the scales have afforded a clew to the habits and movements of the fish. The movements of the smaller animals, such as the crustacea, also prove to be important, since these furnish food to fishes.

The benthos 6. On the floor of the ocean is the assemblage of organisms called the *benthos*. It occupies different levels and environments, according to the depth. The deep-sea animals feed on one another, but existence on this basis alone would be as difficult as that in the mythical island where all the inhabitants got a living

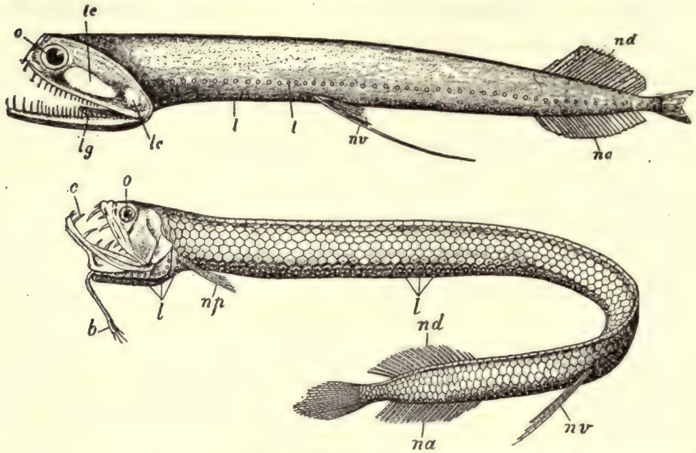
FIG. 205. Foraminifera tests from the bottom of the North Atlantic Ocean; magnified about 10 diameters.

by taking in each other's washing. Ultimately, the source of food is the plant life of the plankton, or the organic materials washed from the littoral zone or the rivers. There is a continual rain of minute organic particles from above, slowly sinking to the bottom. Along with this falls the multitude of shells or tests of radiolaria, foraminifera, and diatoms. Thus the open ocean comes to have its floor composed of such material as the radiolarian ooze, composed of millions of minute tests of these Protozoa. In the deeper seas, life at the bottom exists under peculiar circumstances. It is very cold, and entirely dark, except for the phosphorescence of the animals themselves. The pressure of the water is enormous, but the animals do not feel it, since their internal fluids have a density to correspond. On being quickly drawn to the surface, however, they tend to explode as it were, to fall to pieces. It is not always easy to determine whether fishes have been caught on the bottom, or were captured as the net was being drawn up. Thus, for example, the fish *Alepocephalus* has been taken by many deep-sea expeditions, and was regarded as a typical example of the benthos of the depths; but on one occasion a tow net was dragged about a thousand meters above the bottom, and an *Alepocephalus* was captured.

Our imperfect knowledge of sea life

7. The fauna of the sea affords endless opportunities to the naturalist who wishes to solve scientific and economic problems. Even the easily accessible littoral fauna of our own shores is still imperfectly known; thus many new mollusks have been described from the coasts of California in recent years. The life histories of innumerable forms remain to be investigated. When we come to the deep sea, the extent of the problem is almost appalling. So far, we have

been ablė to glean only about as much as we might of the land if a few balloons dragged nets over the sur-



From Perrier's "Traité de Zoologie"

Fig. 206. Two deep-sea fishes, *Thaumatostomias atrox* (lower) and *Stomias boa* (upper): *o*, eye; *lc*, luminous placques; *l*, luminous spots; *c*, canine teeth; *b*, barbels; *lg*, tongue; *np*, pectoral fins; *nd*, dorsal fin; *na*, anal fin; *nv*, ventral fin.

face of the country on dark nights. How poorly the small collections of miscellaneous fragments thus obtained would represent the life of the earth! In the case of the sea bottom, especially of the greater depths, dredging is so expensive and laborious that it can hardly be undertaken except by governments. Even with public funds, it is possible to explore only an infinitesimal part of the ocean bed within a lifetime. There is thus an endless fascination and mystery about the sea, and the wonders of the deep will probably continue to furnish materials for investigation as long as mankind exists.

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CHAPTER FIFTY-NINE

LOUIS PASTEUR

1. It is related that one of the Paris newspapers, many years ago, asked its readers to vote on the question: Who is the greatest living Frenchman? When the ballots were counted, it was found that the choice had fallen, not on a soldier or politician, but on a plain man of science. It was Louis Pasteur who thus apparently held the first place in the hearts of his countrymen — Pasteur, who had killed no one, but had been the means of saving thousands; who had accumulated no riches, but had enriched whole departments. Probably at no other time, and in no other country, could science have thus been recognized by the people. Nevertheless, as Pasteur himself would have insisted, she constantly deserved such recognition. Pasteur was one of a multitude of investigators, preëminent but not isolated. He stood as the purest example of a type which existed in all civilized countries. **Pasteur's service to mankind**

2. Louis Pasteur was born at Dôle, France, in 1822. His father was a tanner, a man of quite moderate means. As a boy at school, Louis was at first considered rather slow, because he never hastened to conclusions or affirmed what he did not know. Scientific caution seems to have been part of his nature. He early developed a taste for drawing, and after a time his pastel portraits of local celebrities gained him in the vicinity of his home quite a reputation as an artist. At the age of eighteen he became an assistant master in the college at Besançon, with a very small salary. At the same time he continued his studies, looking forward to the École Normale in Paris, which he entered in 1843. Here he came in contact with eminent scientific men, and soon became absorbed in the study of chemistry. **Early life and education**

Researches in chemistry

3. It was during this period that Pasteur made his first scientific discovery. There is an instrument called the *polariscope*, which may be used to test the strength of various substances in solution, such as sugar or tartaric acid compounds. The rays of light, passing through the apparatus, are deflected to the right or left, according to the nature of the substance used. The chemists had worked out a theory of polarization, but there remained a stumbling-block, which no one had been able to remove. Paratartrate solutions, quite contrary to expectation, were neutral, deflecting the light neither this way nor that. We said that Pasteur early exhibited scientific caution, but this means only that he worked carefully, making sure of each step. He had little or none of that so-called caution which frightens a man away from a difficult task. The fact that others had failed was for him a reason for attacking a problem. So he took up the paratartrate puzzle, and presently discovered that when the substance crystallized out, the crystals were not all alike. They were asymmetrical, and one set was the reverse or looking-glass image of the other. Did this mean anything? Separate solutions were made of the two kinds, and immediately the problem was solved. One kind rotated the light to the right, the other to the left, and when they were mixed, they neutralized each other! How very simple! — but none of the chemists who had previously investigated the subject had thought of it.

Pasteur and Biot

4. There was an old and eminent chemist in Paris, named J. J. Biot. On hearing of Pasteur's discovery he expressed incredulity, and wished to see the thing for himself. So one day the young man called at the Collège de France, and was admitted into Biot's laboratory. Biot himself prepared the materials; he would

take no risk of being deceived. In his presence Pasteur picked out the crystals, and stated the expected results.

FIG. 207. Louis Pasteur.

When it all came out exactly as he said, Biot took Pasteur's arm and said: "My dear boy, I have loved science so much during my life, that this touches my very heart!" Thenceforth Pasteur had a faithful friend and supporter in this influential old man.

Marriage

5. In 1849 Pasteur went, as professor of chemistry, to the academy or college at Strasburg, which was then in French territory.[1] He had not been there long, when he fell in love with Mademoiselle Marie Laurent, the

[1] As a result of the recent war, it is once more a French city.

daughter of the rector of the academy. In a formal letter to M. Laurent, he outlines his prospects, and announces that unless his tastes should completely change, he will give himself up entirely to chemical research. Fortune he has none; what should come to him from the family estate he gives to his sisters. His father will come to Strasburg to make the formal proposal of marriage. At the same time, Pasteur ventures to send a more intimate note to the girl's mother. "I am afraid that Mlle. Marie may be influenced by early impressions, unfavorable to me. There is nothing in me to attract a young girl's fancy. But my recollections tell me that those who have known me very well have loved me very much." In due course of time they were married, and we are told that Mme. Pasteur was from the first willing to spell science with a capital S.

Dean at Lille

6. In 1854 Pasteur became dean of the new faculty of sciences at Lille. He entered upon his new work with great enthusiasm, developing the then novel plan of laboratory instruction. He made an opening address to the parents and students, in which he exclaimed: "Where will you find a young man whose curiosity and interest will not immediately be awakened when you put into his hands a potato, when with that potato he may produce sugar, with that sugar alcohol, with that alcohol ether and vinegar? Where is he that will not be happy to tell his family in the evening that he has just been working out an electric telegraph? . . . Your sons will not forget what the air we breathe contains when they have once analyzed it, when in their hands and under their eyes the admirable properties of its elements have been resolved!"

Spontaneous generation

7. With all this zeal for teaching, Pasteur did not neglect his own researches. He presently attacked

what was then supposed to be an insoluble puzzle, that of "spontaneous generation." Did life, in the form of corpuscles or germs, come into existence without having any parents, any ancestors? Many had debated the matter, and wise men had set it aside as incapable of solution, — a subject for cranks, like perpetual motion. This did not discourage Pasteur, nor was he willing to desist when his old friend Biot warned him earnestly that he was wasting his time. After a series of simple but brilliant experiments he was able to prove that the organisms of fermentation and decay, which were supposed to originate in liquids containing organic matter, actually came from the air. Boil the liquids and then exclude the air, and no fermentation takes place, no organisms appear. Thus, after years of futile debate, the matter of spontaneous generation was settled by experiment. Many years before, one Spallanzani, an Italian, had reached similar conclusions, but Pasteur's experiments were far more varied and decisive. The matter was not of merely theoretical interest: the fact demonstrated by Pasteur makes possible the canning industry of modern times.

Diseases of wines

8. On the same principle, Pasteur was now able to investigate the "diseases" of wines, which cause them to spoil on keeping. The exportation of French wines had seriously fallen off on account of the difficulty of keeping them in various climates. The trouble was due to parasitic plants, germs, or corpuscles; or, as we should now say, yeasts or bacteria. These could be destroyed by heating, and thus the difficulty was overcome.

Silkworm diseases

9. In 1865 a new calamity was ruining the silk industry in France. The silkworms perished from two different diseases. *Pebrine* caused the worms to become spotted (the word signifies "peppered") and dry up like

mummies. In *flacherie*, on the contrary, they dissolved into a liquid mass. In either case they perished, and others, brought to replace them, went the same way. J. B. Dumas, a senator of France, was begged to find some one to investigate the matter, and he had no hesitation in choosing Pasteur. People said, who is this chemist, brought here to save the silkworms, of which he knows nothing? Pasteur had, in fact, never seen a silkworm cocoon, and was astonished when the entomologist Fabre explained to him that it would produce a moth. Nevertheless, he knew a great deal about germs of diseases and fermentation, and had no difficulty in perceiving that there existed epidemic, contagious diseases. The proper methods were fairly obvious in the light of what he knew, — to get rid of all diseased insects, and start afresh, with all sanitary precautions. Yet people would not believe in this comparatively simple solution, and Pasteur wished to demonstrate his method on a large scale. He obtained control of an estate belonging to the Emperor Napoleon III, and was able to show the practical value of his ideas in a manner sufficiently public to attract general attention. The silk industry was saved, and with it the livelihood of thousands of peasants.

Pasteur and the Emperor

10. The Emperor interviewed Pasteur, and expressed surprise that he did not make money out of his discoveries. One who could save silk and wine from destruction might well be a millionaire. No, said Pasteur, it is impossible. As soon as one task is accomplished, he must turn to something else, trying to do as much as possible in a short human life. To think of profit would be ruinous to all this. It was sufficient to benefit France, but he did wish to have the means of doing this to the utmost. Carrying out the same idea, we find him begging

the government to build new laboratories. At length a building was in course of erection, when Pasteur fell ill, and many thought he would die. The work stopped, for without him there seemed no object in continuing. It was necessary to appeal to the Emperor to have the building operations resumed, and in the meanwhile Pasteur gradually recovered and was able to return to his labors.

Antiseptic surgery

11. During the Franco-Prussian War of 1870, Pasteur noted with distress the frightful mortality among the wounded. Even slight injuries produced fatal results. Operations in certain hospitals were commonly followed by death. With all his experience in dealing with putrefactive changes, Pasteur fully realized that the trouble was due to bacteria or germs. He could reason from the silkworms to mankind, and recommend the proper sanitary measures. He could see how the surgeons, coming to save life, carried the cause of death on their hands and their clothes. Pasteur, however, was not a medical man, and could not carry out his ideas in practice. Neither could he convince the medical profession, which was by no means ready to take advice from an outsider. It remained for an English surgeon, Joseph Lister, to adopt Pasteur's ideas, and develop in a practical way a system of *antiseptic surgery*. Lister revolutionized surgical practice, though not without meeting a good deal of opposition, and he never failed to express his debt to Pasteur. The saving of life through the new methods has been incalculable. Not only do the wounded recover in large numbers, but operations which formerly would have been deemed impossible are now easy. For example, the operation for appendicitis, now considered hardly dangerous if done in time, would before the time of Lister have been only a last desperate resort.

Anthrax

12. In 1877 Pasteur undertook to combat the anthrax or charbon disease, which was killing great numbers of cattle and sheep. There were places where half the sheep in a flock perished. Even human beings were occasionally attacked. No one knew what to do. The disease was due to a relatively large bacillus, very difficult to destroy. This organism was isolated and described by Dr. Koch of Germany. Pasteur developed a method of vaccination, following the general plan employed for smallpox. It is not necessary here to describe his methods of preparing the "attenuated virus," which he injected into the animals to be protected. The theory of vaccination is based on the fact that the body is able to develop substances which combat or neutralize the poison, and that if it is warned by a weak dose, it will be ready to withstand a strong one. The function of vaccination, then, is not unlike that of the Scotch thistles or the geese at Rome, famous in history.

The vaccination of sheep

The notion of vaccinating sheep did not commend itself to the veterinarians, and, as in the case of the silkworm disease, Pasteur sought a public demonstration. The Melun Agricultural Society put sixty sheep at his disposal. Twenty-five were to be vaccinated twice, and later inoculated with virulent anthrax. Twenty-five others were to be inoculated without vaccination. Ten, untreated, remained to show that the flock was normal. Now, said Pasteur, the unvaccinated sheep, on being inoculated, will perish. The vaccinated ones, also inoculated, will remain healthy. After anxious days, during which even Pasteur feared that something would go wrong, the experiment proved successful, and the whole population joined in applause. Once more an important industry had been saved from destruction.

13. One more great task remained. The disease called *rabies* or *hydrophobia*, communicated by the bite of a dog, had resisted all attempts at treatment. It not only caused perhaps the most frightful death known to medical science, but was the source of terrible anxiety. After being bitten, an individual did not know for many months whether he would get the disease, so slow was its development. The cause, now understood to be a minute protozoan, was not known in Pasteur's time. Pasteur saw, however, that the problem was analogous to that of the other germ-produced diseases, and wondered whether a vaccination method could succeed. Obviously, one could not vaccinate the whole population, of whom only a minute fraction would be likely to be bitten by a rabid dog. It was possible, by using rabbits, to prepare attenuated virus and thus carry out the plan of vaccination. Why not vaccinate after the bite, and get ahead of the slowly developing virus, which gradually made its way to the central nervous system? This might succeed, if too much time had not elapsed and the bite was not too near the brain. The method was worked out successfully with animals, but Pasteur dreaded applying it to a human being, not knowing whether the reactions would be the same. In July, 1885, there came to the laboratory a little Alsatian boy, Joseph Meister, accompanied by his mother. The child had been bitten in fourteen places by a mad dog, and could not be expected to escape the disease. Friends, knowing of Pasteur's experiments, had advised Mme. Meister to appeal to him. He did not know what to say, but after a consultation with his colleagues, resolved to attempt the new treatment. The inoculations, by means of a hollow needle, were at first very mild, but increased in virulence as time went by. Pas-

Hydrophobia

Joseph Meister

teur, dreading evil consequences, spent sleepless nights. It was impossible to draw back; the experiment must be brought to its conclusion. Finally, amid the enthusiasm of all, Joseph Meister was pronounced safe, and the Pasteur treatment for hydrophobia was proved as sound in practice as it had appeared in theory. Money was subscribed, and facilities were provided for the treatment of all bitten persons. The movement eventually spread to other countries, and now almost every part of the civilized world has some laboratory or institute devoted to this and similar work.

Closing years

14. Some years still remained to Pasteur, but toward the end his health failed, and he could work no more. He was surrounded by his colleagues and pupils, who were carrying on the work he had begun, and extending it in every direction. On one occasion they organized a celebration, when Pasteur, seated by the fire and unable to move, received the old students of the École Normale. In the laboratory, on tables, were arranged the little flasks which Pasteur had used in his experiments on spontaneous generation, little tubes used in the investigation of wines, various preparations of infectious germs. At about noon they carried Pasteur into the laboratory, and Dr. Roux, his most brilliant student, showed him the newly discovered bacillus of plague. "There is still a great deal to do!" said Pasteur, as he looked at these things, thinking of the disciples who had gone out from his laboratory to all parts of the world. After this, his strength gradually ebbed away, and he died on September 28, 1895.

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CHAPTER SIXTY

DISEASE IN RELATION TO HUMAN EVOLUTION

The slow evolution of man

1. It is well known that the rate of evolution in various groups of animals differs greatly. Thus the insects have changed much more rapidly than the Protozoa, the mammals more than the insects. Man being a highly specialized mammal, we might naturally expect to find some evidence of evolution in the many thousands of years of his existence. It is true that the Neanderthal man, of extremely remote times, is so distinct that he is regarded as a separate species; but his successor, the Crô-Magnon man, still belonging to the prehistoric period, was a being like ourselves. The finely formed skull is in no way inferior to that of modern races, — is, in fact, superior to some of them. Within historic times new races have arisen, like the English, from the mingling of old ones; but there has been no apparent forward evolution in physical structure. The most we can say is that there has been a shuffling of characters, and probably among civilized nations a slight increase in average size, owing to better nutrition. Man is a variable animal, and his fundamental constancy of type during such a long period may well be used as an argument against the existence of any inherent tendency to progressive modification.

Evolution in resistance to disease

2. Is it a fact, then, that man has remained exactly what he was, except for the mingling of races? Dr. Archdall Reid remarked some years ago that if we wished to determine the direction of modification, we should look for the causes of death. In other words, such modification as may occur is not due to inherent tendencies to change, but to a selective agency acting in the presence of heritable variations. Since individ-

uals who leave no offspring are the true dead from the evolutionary standpoint, the selective agencies must be various. Yet it is evident that the most important factor is disease, particularly the group of diseases due to bacteria. Throughout the centuries, consumption, smallpox, measles, and the rest have attacked mankind and carried off those unable to resist. It is well known to all that the *susceptibility* to particular forms of disease varies greatly, and while this is partly due to physical condition resulting from environment, it is largely a matter of inherited constitution. This is so true that it used to be supposed that consumption was inherited, whereas we now know that what is inherited is susceptibility to that disease. Even among plants the same rule holds; thus a particular strain of wheat is readily attacked by the rust fungus, while another is practically immune. The consequence of these selective processes is the survival of those individuals whose heredity is favorable for resistance, and the production of a relatively immune type. If there are no resistant individuals to be selected, the species may of course become extinct.

Tolerance and immunity

3. The races of mankind afford abundant evidence of adaptation, which we can suppose to have arisen only in the manner described. Thus in tropical Africa the negroes suffer very much less from malaria than the white man, while in the north the white man is more resistant to consumption than the black. There are two different types of adaptation: a race may be *immune* or *tolerant*. If immune, it does not take the disease, does not harbor the parasite. If tolerant, it may readily become infected but suffers little in consequence. In West Africa the negro children carry in their blood the parasite of pernicious malaria, and thus

are a menace to Europeans, to whom it is carried by mosquitoes. In New York State the expectation of life for a negro is very much less than that for a member of the white race. This is doubtless due in part to differences in susceptibility to cold and other climatic factors, as well as to differences in power to resist particular diseases.

Bacterial disease and the survival of races

4. It is a singular fact that in the struggle between allied species or races, the existence of a bacterial disease brought by one of the participants may mean the destruction of the other. This appears to be equally true among plants, animals, and man. Thus the chestnut-blight disease, tolerated by the chestnut of Japan, threatens the extinction of the American tree. Civilized man has destroyed the native tribes of the West Indies, Tasmania, and parts of Polynesia mainly by communicating his diseases. His measles may be more dangerous than his firearms. The adaptive process described above may not take place if the attack is too sudden, or if there is no resistant strain within the population. The groups which now exist have so far been able to leave sufficient survivors in the presence of epidemic disease, but many others have doubtless become extinct.

(For additional details, see the next chapter.)

CHAPTER SIXTY-ONE

HISTORY FROM A BIOLOGICAL POINT OF VIEW

History an aspect of biology

1. HUMAN history is only a special aspect of "natural history," dealing with the succession of events having to do with the species *Homo sapiens.* It continually asks, What has man been through the long ages of his existence? — and the answer, whatever it may be, is also in some measure an answer to that still more interesting question, What may he become? Modern biological research teaches us that particles of living material, having a quite definite composition, pass from generation to generation unchanged. This does not mean that the actual atoms of which they consist are the same, but only that the molecular structure is unaltered, and consequently that these little machines may be expected to act in a like manner under like conditions.

The complexity of mankind

2. We also learn that the human individual is extremely complex, is made up of materials which, however much they may derive their character from ancestral germ plasm, are arranged in new ways, so that it is rarely possible for two individuals to come into the world with the same inheritance of living stuff. Just as a newly written poem may consist only of quite common words, derived unchanged from the language, so the man may be thought of as containing no kind of material which has not existed in many other persons. In spite of this, both the poem and the man are unique, and their value to us depends far more upon the particular sort of combination they represent than upon the elements entering into it. This, at least, if we value them highly; but either may be ruined by unfortunate inclusions, lame words or characters.

Environment and human nature

3. History, then, records the behavior of human beings, so constituted, under different environmental conditions. It has consequently two aspects, the historical in the broad sense, and the biographical. In the first, it seeks to determine the effects of the environment on mankind in general, or on races of mankind. At the same time it asks, What is the duty of man? What is to be expected of this particular sort of creature in this world of ours? Such investigations emphasize the continuity of the germinal substance, the sameness in the midst of diversity.

The uniqueness of the individual

4. On the other hand, the biographical method emphasizes the peculiarities of the individual. The common characters are forgotten, and all the emphasis is laid upon the uniqueness of the heroes or villains who people the stage. This uniqueness appears to spread beyond themselves and to color the lives of their fellows, so that a whole nation partakes of certain characteristics because it has within it an outstanding personality.

The significance of unrecorded events

5. It is a common fault of historians to overemphasize the importance of individuals and events, considered as causes of what follows. Just as we all have a vague idea that certain simple propositions were first formulated in the Bible or by Shakespeare, because we there find the classical expression of them, so the historian is too liable to see a new birth in a salient event. On the other hand, he is likely, from no fault of his own, to be unaware of the time and place of the genuine mutations in human thought and deed. However the stars in their courses may have been moving toward the birth of a new idea, there is a specific moment of time when that idea emerges into the field of human consciousness; and *that* is a genuinely historic event, possibly tingeing and changing the lives of subsequent

generations during the rest of man's existence. Legislative enactments, political disturbances, wars, all the chief materials of historic research, are secondary to these psychological phenomena. Through "social inheritance," whereby the thoughts and experiences of one generation are made known to those following, the thinker becomes the dynamic force in social evolution. It is because of this fact that progress is possible and inevitable, and that the future cannot be accurately predicted from the past. In spite of the continuity of the germ plasm, the sameness of the molecular composition of the human stuff, mankind has learned how to break his bounds and set forth on a journey to which he sees no end.

Social inheritance

The beginnings of history

6. When did history begin? In one sense, with the first germ of life; but we are concerned with a more limited point of view. The ancient man of the Stone Age lived in the caves of France and Spain for many thousand years, without appreciable progress. The emergence of new ideas, the discovery of new methods, additions to his knowledge of the world, were all so few and rare that he could hardly have had any sense of progress. At any given time he was probably unaware of any important change in human affairs, and quite without any suspicion of the fact that he possessed a mind capable of dealing with complex systems of thought and managing miraculous machines. He had no history, in our sense, — much as the moon, within the period of human observation, may be said to have no history. True history begins with events sufficiently important to alter the status of human affairs, and especially when these follow each other fast enough to give a sense of progress, to arouse the expectation of a future different from the past. According to this

interpretation the beginnings of history are coincident with the awakening of the specific powers of man, and do not depend upon the existence of records. The wild men of certain remote regions of the Amazon are still in the prehistoric period.

Tradition and human nature

7. The fact of social inheritance — that is to say, of tradition — complicates in many ways the historian's problem. He must always be asking, is a certain trend of events, a certain way of doing things, due primarily to tradition or to the nature of the human mind? Thus, for example, the remarkable Maya monuments in Central America, dating from a period long before Columbus, appear to show Asiatic influence. They certainly possess characters in common with the monuments of Oriental lands, though in detail quite distinct. Is the degree of resemblance such as may be traced to the common mental characteristics of humanity, or must we explain it by postulating an early discovery of America by Asiatics crossing the Pacific Ocean? Or again, certain stories and legends, such as those of Uncle Remus, appear in various forms on opposite sides of the world, among peoples who have apparently not been in communication. Are they the naïve imaginings of man, in the presence of the universal facts of existence, or have they their root in a widespread tradition having a single place of origin?

Intra-national and international factors

8. History being concerned primarily with the phenomena of human progress, it follows that events *within* the tribe or nation are more important than struggles between nations. It is within the group that true development occurs, and it is rarely that the beginnings of important advances are spectacular. Wars are destructive and retrograde, but the reconstruction periods following them, or even during their progress, may

possess the greatest historical importance. Thus a description of what went on behind the lines may possess more value, may mean more in relation to the future, than one of the heroic acts in battle. From the point of view of general history there is a rather close parallel between wars and epidemics, in that both are destructive, and both necessitate a process of reconstruction during which new tendencies are likely to develop. Both, also, may be so severe and so prolonged that a sort of historic fatigue sets in, and adequate reactions become impossible. Both, again, may select for destruction particular groups of individuals in a mixed population, and thus alter the average quality of the germ plasm of the nation or nations concerned.

The Black Death

9. As an example of the effects of an epidemic, we may take the history of the Black Death, the great plague which devastated Europe in the fourteenth century. It will readily be seen that it resembles in some of its effects that other great European disaster, the war in our own times. The Black Death or Plague is an Asiatic disease, which has at different times invaded Europe. The last epidemic in England of first-class importance was the Plague of London, shortly after the middle of the seventeenth century. The Black Death of the fourteenth century is said to have destroyed half the population in many parts of Europe. F. A. Gasquet, who has given us a vivid account of it, thus describes the reaction of the English in the presence of this great disaster and following it:

"In dealing with this subject it is difficult to bring home to the mind the vast range of the great calamity, and duly to appreciate how deep was the break with then existing conditions. The plague of 1349 simply shattered them. . . . The tragedy was too grave to

allow of people being carried over it by mere enthusiasm. . . . It was essentially a crisis that had to be met by strenuous effort and unflagging work in every department of human activity. . . . Many a noble aspiration which, could it have been realized, and many a wise conception which, could it have attained its true development, would have been most fruitful of good to humanity, was stricken beyond recovery. . . . Time, however, and the power of effort and work remained to those that survived. . . . What gives, perhaps, the predominant interest to the century and a half which succeeded the overwhelming catastrophe of the Black Death is the fact of the wonderful social and religious recovery from a state almost of dissolution."

Social and economic results of the Plague

In the course of this recovery, through periods of rebellion and acute distress, the foundations of better social ideals and conditions were laid, and even the language underwent a change. It had been customary for the educated classes to use Norman-French, which emphasized their distinctness as a social group. A movement existed for the substitution of English in the schools, and Gasquet believes that it succeeded because so many "ancient pedagogues," of conservative tendencies, were removed by the Plague. Thus was laid the foundation of modern English as a basis for literature, and thus were the plays of Shakespeare made possible.

Notwithstanding all these great events and fundamental changes due to the Black Death, the ordinary writers of history have chosen almost to ignore them and to write of the spectacular deeds of the battlefield, of Edward III and his war with France, of Crécy and Calais, and military renown. This, according to them, was the glory of England; but such glory passed away, and the glory which remained was that of the stout

hearts and keen minds which wrought weal out of the very elements of woe.

Epidemic and endemic diseases

10. It would be quite erroneous to emphasize epidemics and military struggles alone, forgetting the tremendous significance of endemic disease and of economic forces in society. These slower processes are hard to grasp, because they are only imperfectly or not at all known to those who are affected by them; the "original sources," the contemporary chronicles, are silent concerning them. Thus there seems to be reason for thinking that the Golden Age of Greece passed away, never to return, not so much on account of wars and invasions, as because of the selective action of malaria. Conquests had brought to the Grecian shores captives of dusky hue, contrasting with the fair folk of aristocratic Greece. The malaria organism, existing in the blood of the conquered, caused them little trouble; they had acquired "tolerance" from long ages of selection. Transmitted to the northerners, the disease killed or debilitated, and gradually the darker races, variously intermarrying with the lighter, came to dominate the civilization. The chances for success in life were in inverse proportion to the amount of northern blood, when malaria became universal. In similar ways we may explain how the northmen, the Normans, firmly established themselves in northern France, but have left no impression on the population of Sicily. All these matters are of course largely speculative, viewed after so great a lapse of time; but we can at least show that similar effects are being produced today, in Africa and Alaska and in the islands of the Pacific.

Racial susceptibility

In the struggle for existence between races, the existence of a mild disease in one is often the undoing of the other. The disease is mild to those races which

have long experienced it, but severe to those who first come in contact with it. Among ourselves, for example, all those strains or groups which could not endure measles have long ago perished, leaving those to whom it is a light matter. To the Indians of Alaska it is a different case; they have undergone no such selective process. To the negroes of West Africa the pernicious forms of malaria, which kill so many Europeans, are not pernicious at all. The negro children run about with the parasites in their blood, and are a menace to white people, to whom these parasites are conveyed by mosquitoes.

Results of differential mortality

11. Great changes in the character of a population will result from differences in the birth or mortality rates, and yet these may be so gradual as to escape observation. Thus if one part of a population produces *two* children for every pair of parents, and another *three*, and each starts with 1000 members, the first group at the seventh generation will have 1000 descendants, the second, 11,391. This assumes that the children grow up and become parents; it takes no account of those who fail to do this, so that the total number of children born is no exact criterion of the vitality of a race. It is easy to see from considerations of this sort that, quite apart from conquests and migrations, changes are going on within the nations themselves. We may pride ourselves on belonging to an ancient people, without realizing that perhaps little is left of that people in those who now bear the name. The biologist will therefore not conclude too hastily that differences in the course of history, in the reactions to environment, are wholly due to external circumstances or the effects of education; they may be due in part to actual changes in the hereditary make-up of the group concerned.

CHAPTER SIXTY-TWO

EUGENICS

Objections to eugenics

1. THE word *eugenics*, proposed by Francis Galton of England, is used to designate the science and art of human breeding, whereby it is supposed that the race may be improved, or prevented from deteriorating. This idea arouses strong prejudice in the minds of many people, because they associate it with animal breeding, in which practical ends are sought without reference to the desires of the animals themselves. Such people also recall that animal breeders follow fashions, and produce or conserve the most grotesque creatures, such as the pug dog or the poodle. They do not wish to see human equivalents of the pug dog or the poodle, and they fully understand that many of the most valuable human qualities are intangible, and incapable of being accurately measured or tested. The excellent human being is such because in him are united many qualities, in a happy combination; and to attempt to create such a one by breeding seems as grotesque as an effort to write poetry by an application of the rules of grammar.

Eminence of certain invalids

2. It may further be objected by the student of history and biography that many of the most valuable men, from a social standpoint, have been invalids, who could never have survived under Spartan rules. Thus, Darwin was a lifelong invalid, Keats was a consumptive, Milton was blind, and so forth. It is a peculiarity of human society, that its success and efficiency depend largely on the existence of individuals who in many cases are personally ill-fitted for the struggle for existence.

3. Even the student of genetics may point out that human beings, especially in civilized countries, are

strongly *heterozygous* (cross-bred), so that it is very difficult to say, from the life record of an individual, what kinds of descendants he is likely to have. Since he will be united with another of diverse character, the matter becomes still more complicated. Numerous instances will occur to most people, in which the children, or some of them, differed greatly from expectation based on the appearance of the parents.

Heterozygous nature of man

4. Nevertheless, although the word *eugenics* is relatively new, the thing itself is no more new than appendicitis. Every one has heard of Spartan methods, crude eugenic efforts dating from remote times. The elimination of the weak has in earlier times and among savage peoples been taken as a matter of course; "but," says Darwin, "we civilized men, on the other hand, do our utmost to check the process of elimination; we build asylums for the imbecile, the maimed, and the sick; we institute poor-laws; and our medical men exert their utmost skill to save the life of every one to the last moment." If it is a fact that in such ways undesirable characteristics are perpetuated, and the number of incapable persons is increased, the matter is serious enough. While it may be true that a few individuals of great merit have poor constitutions, it is no less true that multitudes have the inadequate inheritance without the merit.

Ancient eugenics

5. Although the laws of inheritance have been little understood in the past, we are all familiar with the idea that some persons belong to especially "good families," and that their descent from able ancestors is a matter for boasting. Heraldry would have little meaning apart from this. Considerations of this sort have always had great weight in reference to marriage, and the desire to unite persons of "blue blood" may

Blue blood

be called eugenic. Many romantic stories are based on the supposition that the prince, stolen perhaps as an infant, and raised in a hovel, will still manifest the princely qualities which his heredity has given him. Thus the intuition of a biological fact, forcing itself on the human mind without the aid of formal science, has become the basis of aristocratic claims. Lacking the check of critical investigation, it has been exaggerated to the point of absurdity. Yet there is a background of truth.

Ideals of love and marriage

6. Those who are most prejudiced against eugenics would nevertheless consider it exceedingly reprehensible to marry without any regard to the ability of the parents to take care of their offspring. We should, as a matter of course, consider health and income. Even sordid financial considerations, in so far as they carry with them ability to make a living, may serve eugenic ends. Most of us would probably even admit that the process of "falling in love" is not wholly independent of considerations of the type mentioned. Indeed, natural selection and sexual selection combined must have brought it about that the qualities we admire or love are in general also those valuable to the race. Were the reverse true, the species would have failed in the struggle for existence.

Classification of eugenic measures

7. We see, then, that *eugenics* is a new name for a very old idea, and that in addition to deliberate and planned eugenic practices, there have been innumerable other ones attaining the same ends, usually more or less unconsciously. These latter supplement and grade into the operations of *natural selection* itself. Roughly, we may classify the agencies making toward the improvement of the genetic qualities of the human race as follows:

A. "Natural," i.e., independent of human volition.

B. Due to human volition, but not deliberately eugenic.

C. Purposeful eugenic efforts.

It becomes, therefore, not a question whether influences modifying the race shall exist, but whether, since they do and will exist, we desire to control them in any way. It is difficult to escape our responsibility in this matter. We *have* to a considerable extent the choice of good and evil, and must perforce choose.

The inheritance of defects

8. It is not possible, and were it possible, not desirable, to extend our scientific operations over the whole field, bringing *all* the influences affecting the race under the group *C*. It is a matter for careful consideration, how much we wish deliberately to control. In future ages the increased knowledge and intelligence of man may justify him in attempting what would now be wholly unwise. Nevertheless, enough evidence has accumulated in the last ten or twenty years to prove that certain physical and mental defects are inherited, and are connected with particular determiners in the germ plasm. Thus, two persons having a certain type of feeble-mindedness will certainly have only feeble-minded or mentally defective children. It does not appear very radical or extreme to postulate that no one has the right deliberately to bring feeble-minded offspring into the world. To be sure, those doing this are not capable of judging of their actions; but society is capable, and society may well put forth a restraining hand. Proper institutional care of the mentally defective thus becomes not merely an act of kindness and justice to these unfortunates, but also a most important protection to society itself.

Recessive characters

9. It has been suggested that whereas many of the inherited human defects are *recessive*, it does not matter if one possessing them marries a normal person. The children will be cross-bred, to be sure, but they will appear normal. They in turn will probably marry normal individuals, and the pernicious determiners will never lead to any recurrence of the objectionable characters. With regard to this it must be said, in the first place, that such cross-bred individuals may not be wholly normal. In some cases the heterozygous individuals may be decidedly different from homozygous (pure-bred) dominants, and experienced breeders say that among plants and animals they can often pick them out by critical inspection. More serious, however, is the fact that the recessive qualities do not disappear from the stream of inheritance; their determiners go from generation to generation, ready to produce effects as soon as a chance combination brings them together. Thus they are a trap laid for posterity, and after perhaps one or several hundred years two persons may come together, each with an unknown determiner for feeble-mindedness. One fourth of the offspring will then, on the average, be feeble-minded, and people will wonder at the inscrutable ways of Providence.

Scientific heraldry

10. To what extent may group *C* include measures taken to *increase* good qualities? This is a far more difficult problem, since the complexity of human inheritance is so great. Yet it may be desirable and prudent to pay more attention to the *family record*, as well as to the personal attainments of individuals. Strong objections would be raised to the publication of a mass of unfavorable data, but we can imagine a new sort of heraldry, by which families would be

allowed to indicate in some manner their total achievement. Judgments might be difficult, yet not at all impossible. Galton, in his work on *Hereditary Genius*, has clearly demonstrated the great worth of certain families, and the presumptive value of any individual belonging to them. No one would be *obliged* to favor the groups thus indicated, or pay any attention to family merit; yet it cannot be doubted that if the facts were known in each case they would carry weight. Naturally, the whole procedure would imply the keeping of accurate records, and the government would probably be justified in compiling a "Who's Who" for the entire population.

Environment and social worth

11. Speaking broadly, we may say that it should be the aim of society to create an environment favorable to individuals of high social efficiency. For example, those entering the professions should not have to wait as long as they do at present before possessing the material means to justify marriage. We see today numerous able young men with small incomes, and fewer old ones with ample resources. It cannot be said, from the standpoint of eugenics, that the wealth of the country is well distributed. It is useless to criticize the small size of the families of college graduates as long as economic conditions are unfavorable. Hard facts will outweigh theoretical or sentimental considerations. It is of course true that the standard of living of the educated groups is high, but it would appear a doubtful advantage to lower it, since competition would tend to lower wages correspondingly. It is also necessary to maintain a high standard to give the socially valuable all the advantages of education and other forms of "nurture," without which their powers will be diminished.

Value of prophets

12. It must be remembered that we are concerned not so much with immediate benefits (which must be attained by other than eugenic means), as with the welfare of the race in the long run and the course of time. Hence we should be alive to the value of individuals whose work takes a long time to bear fruit, such as reformers of various kinds and many scientific investigators. William James well said that Saint Paul was poorly adapted to the environment of his day, since he was executed; but he is magnificently adapted to the larger environment of history.

We can make the more subtle and precious human qualities count plus in the struggle for existence only by ourselves appreciating them. Hence the effort to cultivate good morals and good taste is indirectly eugenic, and may become a powerful factor for racial betterment.

Sexual selection

13. Sexual selection must be considered an important eugenic force. It has been objected that sexual selection is of small avail in man, because there is nothing to prevent the marriage of all grades of inferior people. This is not a valid objection, since the union of good qualities conserves them, and in this way the race is provided with a larger number of highly efficient persons, who become very valuable even to the less efficient, when engaged in socialized work. Hence the economic independence of women, and coeducational institutions for higher learning, both serve eugenic ends.

Eugenics and disease

14. We may now return to Darwin's criticism of the preservation of the unfit in civilized countries. We have seen that the *propagation* of those possessing serious inherited defects should be and can be largely prevented. The warfare against infectious disease,

however, is eugenic in so far as it substitutes profitable for unprofitable selection. Smallpox, for example, is strongly selective, but the individuals preserved have *no other* common merit than that of being able to resist smallpox, which is not in itself a valuable social faculty. The ancient saying, "Those whom the gods love, die young," bears testimony to the lack of correlation between the ability to resist disease and any other merit. In so far as useless forms of selection are eliminated, useful ones gain added significance.

The idea of sexual selection in man and the economic emancipation of women give new meaning to Coventry Patmore's beautiful lines:

> Ah, wasteful woman, she who may
> On her sweet self set her own price,
> Knowing he cannot choose but pay:—
> How she hath cheapened paradise!
> How given for naught the priceless gift,
> How spoiled the bread and spilled the wine,
> Which, spent with due respective thrift,
> Had made brutes men, and men divine!

CHAPTER SIXTY-THREE

LOUIS AGASSIZ

The reputation of Agassiz

1. Perhaps the most picturesque figure in the history of biology is that of Louis Agassiz. Equally famous in Europe and America, combining a remarkable intellect with much of the naïve simplicity of a child, he appealed to the public in a way which has rarely been approached in the annals of science. While he was professor at Harvard University, his popularity led to a certain amount of natural jealousy. Why is it, people said, that every one talks of Agassiz? Is his work so tremendously important that everything he does must be immediately reported and discussed, while the profound researches of other men go unnoticed? It was not Agassiz's fault. He was one of the greatest of naturalists, but whatever he might have been, people would have been fascinated by his presence, his tremendous enthusiasm. Few have such gifts, but those who have them may do great things for science and education.

Early years in Switzerland

2. Louis Agassiz was born at Motier, in Switzerland, in 1807. His father was the pastor of the village. Louis, like other Swiss boys, was keenly interested in the life of the meadows and lakes, forests and mountains. He early accumulated collections of specimens, and also had many pets. At the age of ten he was sent away to a school at Bienne. Here he remained for four years, and toward the end of that period wrote out a statement of his future plans, — rather remarkable ones for a fourteen-year-old boy! "I wish," he wrote, "to advance in the sciences. . . . I should like to pass four years at a University in Germany, and finally finish my studies at Paris, where I could stay

about five years. Then, at the age of twenty-five, I could begin to write." The parents had intended

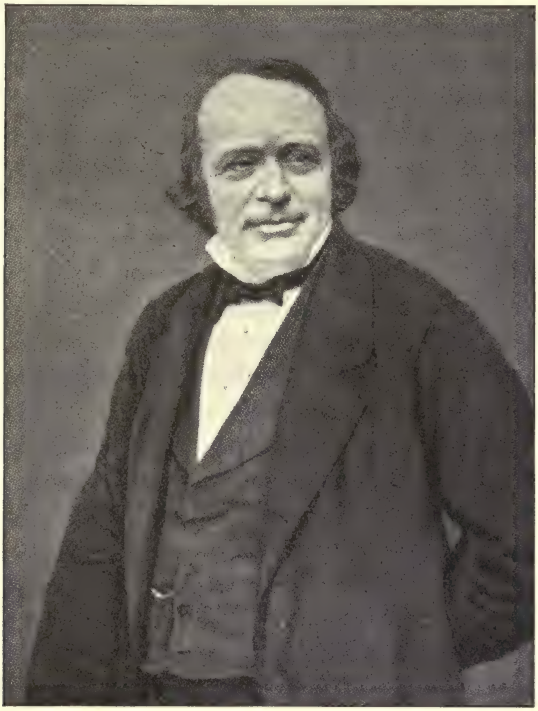

FIG. 208. Louis Agassiz.

Louis for a commercial life, but the boy's hopes and ambitions led in other directions, and medicine was substituted. After two years at the College of Lausanne, he went to the Medical School at Zürich, and in 1826, at the age of nineteen, to the University of Heidelberg in Germany.

University life in Germany

3. The four years of university life in Germany were divided between Heidelberg and Munich. The new university at Munich had opened under brilliant

auspices, with a remarkable faculty, and was attracting many students. So, after a year at Heidelberg, Agassiz decided to migrate, and with him went his greatest friend among the students, Alexander Braun. Many records exist, showing the intensity of Agassiz's life in the university. With his friends Braun and Schimper he seemed able to attack every difficult problem. The three were so closely associated that the students called them the "Clover leaf." After the day's work these men, with a few others, would meet and deliver lectures. The association thus formed came to be known as the "Little Academy," and eminent men would often look in upon it, with expressions of interest and sympathy. The young lecturers deemed all this valuable experience, "since," they said, "we all desire nothing so much as sooner or later to become professors in very truth, after having played at professor in the university." Their poverty was no check to their activities, and their life was picturesquely bohemian. Braun, in his letters home, gave some graphic descriptions: "A live gudgeon with beautiful stripes is wriggling in Agassiz's washbowl, and he has adorned his table with monkeys. We stay together in his room or mine by turns, so as not to need heat in two rooms, and not to burn twice as much for light. . . . Under Agassiz's new style of housekeeping, the coffee is made in a machine which is devoted during the day to the soaking of all sorts of creatures for skeletons, and in the evening again to the brewing of our tea." More and more, zoölogy became the passion of Agassiz's life, and the studies in medicine, ostensibly the occasion of his presence at the university, were increasingly neglected.

Agassiz, Braun and Schimper

4. Several years earlier the King of Bavaria had sent an expedition to Brazil, to collect specimens of natural history. The results of this journey were in course of publication in a number of sumptuous volumes, but in 1826 the author of the zoölogical series died. This left the fishes undescribed, and when the editor looked around for a suitable man to deal with this subject, he decided upon the young student Agassiz. This was an extraordinary compliment, and although it meant still further encroachments upon the time devoted to medical studies, the task was gladly accepted. In due time the book appeared, and Agassiz, justly proud, writes with enthusiasm to his sister Cecile: "Will it not seem strange when the largest and finest book in papa's library is one written by his Louis?" **The fishes of Brazil**

5. Having duly graduated at Munich, Agassiz returned to Switzerland, where he made a certain pretense of setting up a medical practice. He was, however, now filled with ideas of writing great works on fishes, and particularly on fossil fishes, a subject then greatly neglected. So we find him going to Paris, approximately carrying out the plans he made when a boy. Here he sought the acquaintance of Cuvier, an aristocratic genius, the first zoölogist of his time and one of the greatest leaders of French science. Cuvier received him politely, and soon began to take a strong personal interest in his work. After a time, when thoroughly satisfied of the young man's ability, Cuvier produced a portfolio of notes and drawings of fossil fishes. This he placed in Agassiz's hands, saying that he had himself intended to prepare just such a work as Agassiz had in view, but he now saw that his young friend was the proper man to do it. Would he, there- **Fossil fishes** **Cuvier and Humboldt**

fore, accept these accumulated materials to use in any manner he thought best? Agassiz, communicating the news to his grandfather, writes: "You can imagine what new ardor this has given me for my work; . . . I work regularly at least fifteen hours a day, sometimes even an hour or two more; but I hope to reach my goal in good time." Even after this, Agassiz was almost compelled to abandon his labors and return prematurely to Switzerland, on account of lack of means. Fortunately another great scientific man, Alexander von Humboldt, learned of his distress and generously supplied him with a considerable sum of money.

Return to Switzerland

6. Agassiz went to Neuchâtel, Switzerland, in 1832, and remained until 1845. During this time he taught and wrote, and although he had great difficulty in making a living, this was the period of his most brilliant and important scientific work. In 1833 he married Cécile Braun, the sister of his greatest friend. From 1833 to 1844 the great work on *Fossil Fishes* (*Recherches sur les Poissons fossiles*) appeared in parts, with hundreds of plates. Agassiz had developed a classification which depended largely on the character of the scales, but it subsequently appeared that some of his groups were unnatural, and his methods were abandoned. In quite recent years the scale work has been taken up again, and the result has been to confirm fully the value of scales for classification, though the interpretations of Agassiz prove in some cases unsound. Much work was done on fresh-water fishes also, on fossil echinoderms, and other subjects, the titles of books and papers issued during the Neuchâtel period numbering about 150. The most remarkable new work, however, was on a subject wholly unconnected with

zoölogy, though it afterwards came to have a very important bearing on all theories of the distribution of animals and plants. The Swiss naturalist Charpentier had observed that many boulders scattered over the meadows and valleys of Switzerland consisted of rock which did not occur in place in the vicinity. The herders called them *rôches moutonnées*, or "sheep rocks," because they resembled resting sheep and sometimes deceived those in search of their lost animals. As early as 1815 a mountaineer named Perraudin had called attention to these rocks, and had suggested that they had been brought by glaciers which had since melted away. This view was supported by the engineer Venetz, and finally was brought before the scientific world by Charpentier, who presented convincing evidence.

The glacial theory

Agassiz, then, did not originate this idea; but he saw that if Charpentier was right, much more followed than that able man imagined. If Switzerland had once been buried in ice to the extent claimed, how could the climate producing such an effect be restricted to this small area? Must not all northern Europe, and even North America, show similar phenomena? Thus was developed the great glacial theory, which is now a commonplace of geological science. In many countries "erratic boulders," as they are called, were found, and also scratches on the rock left by the grinding masses of ice. Naturally such an astonishing conception was not accepted unchallenged. People said, Why does not Agassiz stick to his fishes, which he understands, instead of setting forth such crazy notions, belonging to a field in which he is no expert? Gradually, however, the facts came to notice, and geologists were compelled to accept the theory practically as Agassiz

presented it. Today we recognize several periods of glaciation, with warmer intervals; and any one traveling across America in a train can recognize the glaciated areas by their topography.

Agassiz in America

7. As time passed, Agassiz's financial condition got worse and worse, until it was really desperate. Something had to be done. At this juncture the king of Prussia, through Humboldt, offered Agassiz some three thousand dollars to be spent in scientific travel; and the Lowell Institute at Boston asked him to deliver a course of lectures. Consequently, in October, 1846, Agassiz arrived in Boston, and gave his first series of lectures, on "The Plan of Creation." He had little experience in speaking English, but he could illustrate his meaning by drawings in chalk; and from the first his audiences were not merely sympathetic, they were charmed. No one in this country had ever been able to make natural history so interesting. Agassiz, on his part, was amazed and delighted at the warmth of his welcome and the amount of money he was able to make. At last the burden of debt was lifted, and he was square with the world. He meant to return, of course, but he had not been long in America when he learned of his wife's death, and gradually the home ties seemed to weaken, as those connecting with the New World strengthened. In 1848 he was offered a professorship at Harvard University, and in view of the then disturbed state of Europe, he was glad to accept. The following year he married an American lady, Elizabeth Cabot Cary.

ıe teacher American ölogists

8. From 1848 to the time of his death in December, 1873, Agassiz devoted himself to the development of American zoölogy. In this quarter of a century he did much work of his own and planned much more,

but his researches were not equal to those carried out during the brilliant thirteen years in Switzerland. There were perhaps too many distractions, and whereas he had formerly struggled bravely against difficulties, he now seemed to suffer from a surplus of opportunities. In America, however, he is remembered chiefly as the great teacher, — the one who, whatever he did himself, stimulated others as no one else could do. No doubt all the ablest men in the country with zoölogical leanings flocked to him; he had before him the best material America could furnish; but all those who labored successfully under his guidance united in their tribute to his power as a teacher. Others there were with whom he could do nothing; he made no concessions to laziness or want of zeal, but expected to find industry and enthusiasm resembling his own.

Longfellow and Agassiz

9. In 1857 Agassiz was offered a professorship in Paris, a position which earlier in his life would have seemed to represent the very pinnacle of his aims. Amid much enthusiasm in America, he declined, though the offer was renewed and pressed upon him. It was in this year, on the occasion of his fiftieth birthday, that Longfellow wrote the charming verses:

It was fifty years ago,
In the pleasant month of May
In the beautiful Pays de Vaud,
A child in its cradle lay,

And Nature, the old nurse, took
The child upon her knee,
Saying, "Here is a story book
Thy Father has written for thee —

"Come wander with me," she said,
"Into regions yet untrod;
And read what is still unread
In the manuscripts of God."

And he wandered away and away
With Nature, the dear old nurse,
Who sang to him night and day
The rhymes of the Universe.

And whenever the way seemed long,
Or his heart began to fail,
She would sing a more wonderful song
Or tell a more marvelous tale.

*   *   *   *   *

Evolution

At Cambridge Agassiz's warmest friends were the great New England writers, Longfellow, Lowell, Holmes, Emerson, and the rest. With the purely scientific men he was somewhat less in accord, partly on account of differences in temperament, and partly because they were becoming disciples of Darwin, whose theory of evolution he could never bring himself to accept. His students who afterwards became eminent naturalists, men such as Jordan, Scudder, Dall, Shaler, Packard, Hyatt, Verrill, Morse, Garman, and the rest, all accepted evolution; but they were of a later generation. Agassiz, in 1859, could not make over his biological philosophy.

The Agassiz Museum

10. During the last fourteen years of Agassiz's life, his interests centered around his museum, the corner stone of which was laid in 1859. Officially it is the Museum of Comparative Zoölogy of Harvard University, but every one calls it the Agassiz Museum. It is not one of the largest museums of the world, such as the British Museum, but it is devoted to the exhibition, in compact form, of the whole animal kingdom. It is designed for teaching and research, not for a great national storehouse. In its strength and its limitations it is a typical university museum, with scarcely an equal anywhere. Agassiz obtained for it not only private legacies and gifts, but actually

induced the legislature of Massachusetts to grant a large measure of support. Legally, it might belong to the Harvard Corporation, but it was in all essentials a public insitution, free to those who cared to make use of it.

Journey to Brazil

11. In 1848 Agassiz visited the shores of Lake Superior, and in 1850 the Florida reefs. In 1865–1866 he went with his wife and a company of young naturalists to Brazil, to explore the waters of the Amazon and other rivers, and meet in life the fishes he had described so long ago at Munich. One of his assistants on this expedition was William James, afterwards famous as a psychologist. Thanks largely to the aid of Dom Pedro, the Emperor of Brazil, the expedition was extremely successful, and the collection of fishes made was enormous. Agassiz thought he had about 1800 new fishes from the basin of the Amazon, but he never found the time and strength to describe them. They are still preserved at the Museum of Comparative Zoölogy, and have been studied by many ichthyologists.

Hassler expedition

In 1871–1872 Agassiz went in the Coast Survey vessel *Hassler* to California by way of Cape Horn. It was a long voyage, and his health had been poor, but he was delighted with the opportunity to see so much marine life. He thought that in the deep sea he would find a fauna resembling that of early geological epochs. In spite of his enthusiasm, however, the state of his health could not be forgotten, and when they finally reached San Francisco, Agassiz was brought home without attempting to see the wonders of California or the Rocky Mountains.

12. It seemed, indeed, that he was a broken man, but once more his splendid energy declared itself. He

Summer school at Penikese

had long wished to carry on his teaching by the sea, where marine life could be studied in its natural environment. A plan was formed for a summer school of natural history, a biological station. Today the idea is commonplace, but then it was a wonderful new experiment. The island of Penikese, off the coast of Massachusetts, was offered for his use, together with a considerable sum of money. On July 8, 1873, surrounded by a carefully chosen group of students, men and women, Agassiz opened the Penikese school. Mrs. Agassiz relates that "as he looked upon his pupils gathered there to study nature with him, by an impulse as natural as it was unpremeditated, he called upon them to join in silently asking God's blessing on their work together." Whittier has immortalized this moment in a poem:

On the isle of Penikese,
Ringed about by sapphire seas,
Fanned by breezes salt and cool,
Stood the Master with his school.

Said the Master to the youth:
"We have come in search of truth,
Trying with uncertain key
Door by door of mystery;
* * * * *
We are groping here to find
What the hieroglyphics mean
Of the Unseen in the seen,
What the Thought which underlies
Nature's masking and disguise,
What it is that hides beneath
Blight and bloom and birth and death.
By past efforts unavailing,
Doubt and error, loss and failing,
Of our weakness made aware,
On the threshold of our task
Let us light and guidance ask,
Let us pause in silent prayer!"

Then the Master in his place
Bowed his head a little space,
And the leaves by soft airs stirred,
Lapse of wave, and cry of bird
Left the solemn hush unbroken
Of that wordless prayer unspoken,
While its wish, on earth unsaid,
Rose to heaven interpreted.

*   *   *   *   *

Returning from Penikese, Agassiz looked forward to renewed activities of all sorts, but his time was drawing to a close. As late as the 2d of December he delivered one of his characteristic lectures, but from that time he rapidly failed, and died on December 14, 1873. He was buried in Mount Auburn Cemetery, and his tombstone is a boulder from the glacier of the Aar, not far from the place where so long ago he studied the movements of the ice. **Last days**

The island of Penikese is now a leper settlement; but at Woods Hole, on the coast of the mainland, is a large and important biological station and summer school, where Agassiz's plans and hopes are realized in the fullest manner. Not only this, but on many other coasts such schools have been founded, and throughout the world the impetus given to the study of natural history by Agassiz is still a living force.

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CHAPTER SIXTY-FOUR

SPENCER FULLERTON BAIRD AND THE UNITED STATES NATIONAL MUSEUM

Early life

1. SPENCER FULLERTON BAIRD was born at Reading, Pennsylvania, in 1823. His ancestry was mixed, — English, Scotch, and German. He early lost his father, and his mother, with her seven children, moved to Carlisle, Pennsylvania. Spencer Baird and his brother, William, began in their early "teens" to collect birds. As in the case of Darwin and many other famous naturalists, the love of collecting was the foundation of a scientific career. With the specimens, data or facts were also collected, and all had to be set in order. This gathering of materials and arranging them is the method of science; further developments merely result from the growth of experience and opportunity.

Inborn traits

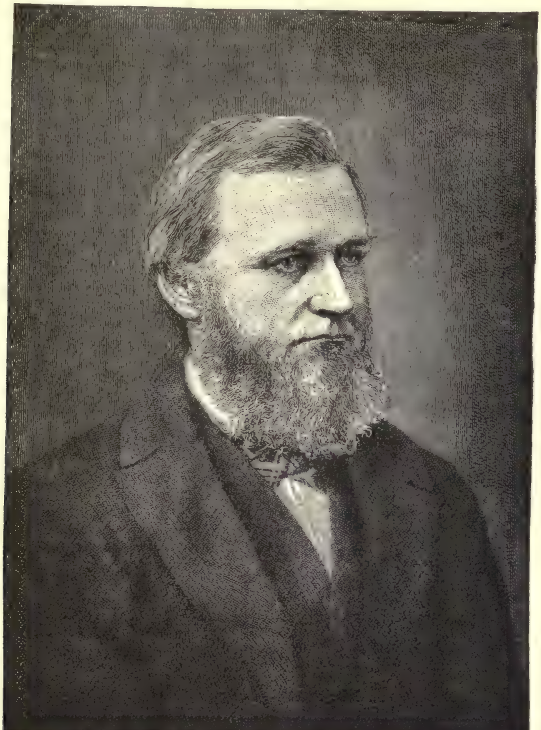
Baird's diary at the age of sixteen shows some of the qualities which distinguished him through life. On May 25, 1839, he writes:

> About one A.M. gust came up; light wind — some thunder — rained violently for one quarter hour. Very warm all day. About two P.M. went out to creek with gun. Shot some small birds, principally flycatchers. Home at seven. Skinned and opened birds until ten.

These are unimportant details, but they show a love of precision, a quality fundamental for good scientific work. In later years this attribute had an important bearing on the development of American ornithology. Dr. D. S. Jordan says of Baird:

> He taught us to say, not that the birds from such and such a region show such and such peculiarities, but that "I have the following specimens, which indicate the presence of certain peculiarities in the birds of certain regions. The first was taken on such and such a day of such a month, at such a place, by such a person, and is numbered so and so on the National Museum records." Thus it was always possible to distinguish between the things Baird knew and those he surmised, and to refer to the very specimens on which he based his opinion.

2. It was not long before Baird made a genuine discovery, of a bird entirely new to science. We find him **Audubon and Baird**



After a woodcut in "Science"

FIG. 209. Spencer Fullerton Baird, from a photograph taken about 1865.

timidly writing about it to the great naturalist Audubon: "You see, sir, that I have taken (after much hesitation) the liberty of writing to you. I am but a boy and very inexperienced, as you no doubt will observe from my description of the flycatcher." To this letter Audubon replied:

On my return home from Charleston, South Carolina, yesterday, I found your kind favor of the 4th instant, in which you have the goodness to inform

me that you have discovered a new species of flycatcher, and which, if the bird corresponds to your description, is, indeed, likely to prove itself hitherto undescribed; for, although you speak of yourself as being a youth, your style and the descriptions you have sent me prove that an old head may from time to time be found on young shoulders!

The bird was in due time described and named by the brothers Baird, and is everywhere recognized today as a valid and distinct species. This was only the first of a series of such discoveries.

Medical education

3. Baird graduated from Dickinson College, at Carlisle, and it became necessary for him to consider a career. He wished to be a naturalist, but that occupation was hardly likely, it then seemed, to lead to fame or fortune. After much discussion in the family, in which young Baird found a strong supporter in his grandmother, it was decided to send him to a medical school in New York. There he would continue his scientific studies, and the profession of medicine would suitably combine biology with breadwinning. As with Baird, so also with Agassiz, Darwin, Huxley, and others: medicine was sooner or later abandoned for pure science, but the knowledge gained in the medical school was by no means wasted. On going to New York, Baird soon made the personal acquaintance of Audubon, and became closely associated with him. He also sought out all the other notable zoölogists of that part of the country and of Philadelphia. During the holidays he continued his field work; in 1843 his diary states that he had walked about 1400 miles during the year.

Professor at Dickinson College

4. On his return to Carlisle, Baird did not take up the practice of medicine; indeed, he had not even taken his medical degree. Instead, he was appointed professor of natural history in Dickinson College, when only

22 years of age. As a teacher he was indefatigable and resourceful. He had nothing resembling the luxurious laboratories of today, and it was often necessary for him to manufacture his own apparatus. Whenever he could, he took his classes for long rambles, — botanizing, geologizing, and collecting the birds, mammals, fishes, and reptiles of the neighborhood. However, this professional period was short, lasting hardly five years, new opportunities and duties calling Baird to Washington.

The Smithsonian Institution

5. The Smithsonian Institution, in Washington, had been founded for the diffusion of knowledge. It took its name from that of Smithson, an Englishman, who had left a sum of money to the United States Government for the establishment of such an institution. Professor Henry, an eminent physicist, was in charge. The funds were limited, and there was much discussion as to how they should be spent. The terms of the Smithson bequest were vague enough to allow much latitude of choice, and advice was offered from all quarters. It was quite plain to Henry that he could not do *all* the things proposed, that he would dissipate his funds and accomplish nothing of value. He therefore tried to restrict his activities as much as possible, and especially sought to avoid duplicating what was being done elsewhere. He did not wish to establish a museum, knowing well the enormous cost, but he found himself the custodian of certain collections belonging to the government, for which no other place was available. He therefore asked for an assistant, to take care of these materials and otherwise aid in the work of the Smithsonian. When his request was granted, he at once selected Baird, who entered upon his duties without delay.

Founding the National Museum

6. Henry dreaded the growth of a great museum, because he knew that the available money was quite inadequate to support it properly. Baird went to Washington full of the idea of building up a museum, ardently wishing to see a National Museum which should eventually rank with those in London, Berlin, and Paris. There was here a conflict of purpose, which might easily have led to difficulties, but the relationship between the two men was always ideal, without a cloud. Baird was one of those tireless, ingenious, persuasive men who always get what they wish, and make people glad to give it. Thinking always of his cause, never asking anything for himself, he captivated congressmen and others by his sincerity and honesty. Financial support was granted, and when Henry saw that the Museum was to be taken care of by the nation, and would not have to depend on the slender resources of the Smithsonian, he was readily won over to Baird's point of view. The efforts made by Baird to increase the collections were innumerable. Government expeditions were always expected to return with valuable materials, but he also sought and obtained the aid of private persons. He would correspond with any and all who could possibly help, doing all kinds of personal services for them in return for their contributions. There was a very able naturalist, Robert Kennicott, who had a plan to explore the little-known country about Hudson Bay. Baird sat down and wrote to numerous naturalists in these terms: "We are sending Kennicott to Hudson Bay, I am myself subscribing \$50, and we expect great results. Will not you similarly subscribe, and take your share of what is obtained?" In this way about \$500 was collected, and Kennicott set forth. The results were excellent, and

Photograph by Smithsonian Institution

FIG. 210. The Smithsonian Institution.

Photograph by Smithsonian Institution

FIG. 211. The new building of the United States National Museum.

today one may find references to them scattered through the literature of American zoölogy. About the same time there appeared another naturalist, John Xantus,

who wished to visit the Peninsula of Lower California, a region even less known to zoölogists than that of Hudson Bay. Baird knew that he could not very well raise a second $500 subscription, and so he hunted around for another way. He found that the United States Coast Survey had planned to send a man to that region to investigate the tides, for the safety of the merchant vessels which passed up the Pacific Coast after doubling Cape Horn. Why not send Xantus? So it was arranged, and today the name of Xantus is inseparably associated with Lower Californian zoölogy.

Encouragement to young naturalists

7. Devoted as he was to the Museum, Baird never lost sight of the fact that it was not an end in itself; he and it existed to serve the American people. So we find him aiding and encouraging every budding naturalist, every boy who might show the slightest interest in science. Letters on all sorts of topics poured in upon him and were always courteously answered, the information desired being given whenever possible. Some who afterwards became famous were thus stimulated by Baird, when young and unknown. One evening a week his house was thrown open to scientists, young and old, and those who gathered about him became his devoted friends, ready to serve him in return for the kindness he had shown. In the Museum, as it came to have a considerable staff of workers, Baird daily made the rounds of the rooms, giving sympathy and encouragement to all.

Baird and Mason

8. As an example of Baird's attitude toward young men, we may cite a story told by Dr. O. T. Mason. Long years ago, when Mason was a youth, he heard that the Smithsonian had received some Semitic inscriptions which had lain without being unpacked for some time, nobody taking much interest in them. Mr. Mason

hastened to the Museum, for he had already become much interested in Semitic ethnology and expected to make it the chief study of his life. Professor Baird received him most cordially, and placing his hand on his shoulder said, "These things have been waiting for you for six months." So they were unpacked and set out where they could be seen; Professor Henry came in, and the three went over them carefully, the young man explaining them as well as he could in the light of his studies. When it was all over and Mr. Mason was about to go, Baird turned to him and said, "Now I want you to give all this up." While the young man almost gasped in astonishment, Baird continued: "If you devote your life to such a subject as this, you will have to take the leavings of European workers. It will not be possible for you here in America to obtain the material for important researches; but — *I give you the two Americas!*" Dr. Mason, telling the story when an old and distinguished man, said, "I was born again that day."

Monographs on American zoölogy

9. In the meanwhile Baird undertook gigantic researches of his own. His activities covered the whole field of North American vertebrate life. As early as 1857 he published a great work of over 800 pages on the American mammals, and a year later a still larger monograph on the birds. So great was his influence on American ornithology that Dr. Coues, writing on the history of the subject, sets aside a period of almost thirty years as the "Bairdian Period." Not only was Baird's work influential in his own country, but across the water, in Europe, men took note of his exact methods and followed them. As the Museum grew, executive duties became heavier and more numerous; and in 1878, when Professor Henry died, Baird became

Secretary of the Smithsonian

head of the Smithsonian. The result was the abandonment of Baird's personal researches, and his total absorption in the work of managing and helping others. Much of his energy went into efforts to secure funds for a new building, — efforts which were finally successful, thanks in part to the numerous workers who enthusiastically came to his aid. Today, still another and larger National Museum building has been erected, and it is already crowded.

The Fish Commission

10. Toward the end of Baird's life another great opportunity came to him, and he hastened to meet it, overburdened with duties as he already was. President Grant was authorized to appoint a competent man to inquire into the state of the fisheries, and devise means for the increase or protection of the fish supply. Baird was appointed, and instead of making a superficial inquiry and issuing a report, he took up the whole problem in a scientific spirit, and undertook to establish the foundations of a new and fruitful policy which should govern the fisheries, both marine and freshwater. He established a permanent organization, which is still in existence, and built a biological laboratory by the sea, at Wood's Hole, on the coast of Massachusetts. The results exceeded all expectations, and European workers in the same field, at first incredulous, were presently enthusiastic followers of Bairdian methods. Although since Baird's time the Commission or Bureau of Fisheries has unfortunately suffered from political influences, the scientific basis of all the work has never been lost sight of, and the publication of important theoretical and practical results has continued without a break.

11. At length the incessant work told upon Baird's originally robust health, and he was advised to rest.

Reluctantly he accepted the decision of the doctors, but it was too late. The end of his life, at Wood's Hole, is thus described by Major Powell:

Last days at Wood's Hole

For many long months he contemplated the day of parting. Labor that knew no rest, responsibility that was never lifted from his shoulders, too soon brought his life to an end. In the summer of 1887 he returned to his work by the seaside, that he might die in its midst. There at Wood's Hole he had created the greatest biologic laboratory of the world; and in that laboratory, with the best results of his life work all about him, he calmly and philosophically waited for the time of times. Three days before he died he asked to be placed in a chair provided with wheels. On this he was moved around the pier, past the vessels which he had built for research, and through the laboratory, where many men were at work at their biologic investigations. For every one he had a word of cheer, though he knew it was the last. At the same time, along the pier and through the laboratory, a little child was wheeled. "We are rivals," he said, "but I think that I am the bigger baby." In this supreme hour he was playing with a child. Then he was carried to his chamber, where he soon became insensible and remained so until he was no more.

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CHAPTER SIXTY-FIVE

SOCIOLOGY FROM A BIOLOGIST'S POINT OF VIEW

Emotional appeal of sociology

1. A PURELY objective sociology, regarding dispassionately the phenomena of human society, is scarcely desirable. It may be considered more "scientific" or "academic" to review the subject as we might the natural history of snails; but one who is trained to study humanity unmoved does not make a very good citizen. There is an optimum state of mind somewhere between the extremes of cold scientific analysis and irresponsible emotionalism. The naturalist Wallace said in his old age that he had come to believe that no one deserved credit for his opinions, but only for the acts resulting from them. Faith without works is sterile, even though it be scientific faith.

The scientific basis

2. We must, however, guard ourselves against the assumption that "pure science" is valueless, when it appears to have no practical outcome. The study of snails, or of any other phase of natural history, contributes to that basic philosophy which underlies the conduct of civilized man. Our sense of security, our reliance on the order of the Universe, whether we call it God or by some other name, depends upon our assurance that system prevails rather than chaos. It is the task of science to study the book of nature, and demonstrate that the letters in it spell words, the words make sentences, and the sentences embody the law which all must obey. Thus no scientific work is sterile, provided it really interprets or reveals natural order.

Thought and action

3. Why, then, should not sociology be treated as a "pure science"? It may be so treated by a certain number of specialists; but whereas many studies con-

tribute to our general idea of nature without suggesting practical applications, it is impossible for a sensitive and thoughtful person to study his species without wishing to act. It is also difficult or impossible for him to believe that the methods of scientific investigation cover the whole field. He will never assent to the proposition that those whom he loves can be described or defined wholly in terms of anatomy and physiology, physics and chemistry. In his reaction against such conceptions, he is likely to make the serious mistake of undervaluing the contributions of biology and their meaning for society. The young, however, are at once relatively plastic and callous, — plastic because their lives are developing, and many choices are still open; callous because experience has not yet filled the imagination, and many things consequently possess little suggestive significance. The educational process inevitably works an injury when it creates the habit of thinking without acting, where action should naturally follow. It is apparently only too possible almost or quite to eliminate the desire to act. It is for this reason that sociology, as an educational subject, should be something more than "pure science," — should be dynamic and purposeful, though it stirs the waters of discontent.

4. The biologically trained individual sees in society a persistent attempt, more or less unconscious, to attain harmonious relations with the environment. This environment changes from year to year, largely through the actions of man himself; hence progress is inevitable. The growth of human law, "from precedent to precedent," typifies the accumulation of experience, translated into rules of action. Athwart all this comes modern science, with her novel discoveries, and com- **Adaptation**

mands attention with an authority rising above that of legislatures. The scientific man is the modern prophet, bearing a message from on high, — truly such, with little metaphor. When Pasteur revealed the connection between wound fever and bacteria, it did not matter if all surgeons prior to his time had acted on a different supposition. Truth rose above custom, and the denial of her message cost innumerable lives. Now it may always be said, not without some measure of justification, that the scientific dictum is based on a narrow point of view, — that the total experience of mankind, derived from untold centuries of history, may indicate truths not appreciable in the laboratory. It may be so, doubtless is so in some measure; but mankind can no longer afford to neglect or disobey the word of science.

Failure and success

5. Thus the student of society has to contemplate on the one hand an inspiring record of progress, and on the other a disastrous chronicle of failures. His practical task is to determine what causes have led to the one and to the other. How can the good be increased, the inevitable error and evil diminished? If he is scientifically trained, he does not look for his answers in the writings of the past, any more than he seeks guidance for himself in some chronicle of his childhood. We, who live today, are the mature people, who must think and act in accordance with the stature to which we have risen. The new point of view, if fully adopted, would make over our whole system of government and would enable us really to take advantage of the powers of the human mind.

Socialization

6. Having thus gained a point of view, we may discuss a few practical applications. At the outset it appears that the application of scientific methods

demands increased socialization. That is to say, new social activities are needed, and must be met by taxation. The water supply, the public health, education, and many other things come under social direction. Experts are employed to do things which could not be intelligently done by the average citizen. The increased burden of taxes, which naturally becomes a cause of complaint, does not necessarily involve greater expenditure per capita. Private functions have become public ones, and the actual amount expended may be decreased. Still the social standard of living rises, and such things as public parks, which would formerly have been considered luxuries, come to be regarded as necessities. In the educational field higher education is more and more taken as a matter of course.

Possibilities of human progress

7. Yet it becomes evident that even with expert guidance the whole is limited by the condition of its parts. Scientific discovery has today gone far beyond scientific application. Without an educated and intelligent community, the dreams of sociologists can never be realized. It may be said of some projects, that they postulate a population of angels or supermen; that the limitations of humanity forever render them impossible. While this may be true, one who studies the history and nature of man must be convinced that he is capable of enormous advances. We have never yet tried the plan of giving every one the best chance which society can afford. In our blind and reckless way we have always sacrificed the prosperity and happiness of untold numbers in order to attain ends having little or no social value. The new sociology, rightly applied, suggests at once the wickedness of past methods and the way out. But it never can be intelligently applied by ignorant people.

Infant mortality

8. It is useful to make a study of some particular field of endeavor, and perhaps none is more instructive than that which deals with infant mortality. Dr. G. B. Mangold shows that in 10 years the death rate of infants under one year in New York City declined 31 per cent. In Los Angeles the improvement, according to published statistics, was actually 43 per cent. For the states included in the registration area in 1900, the decline from 1900 to 1911 was 22 per cent. To what is this due? Broadly to education and the liberalization of public opinion, both going back to scientific research for the facts on which to proceed. Organization on the one hand, and individual initiative on the other, have worked this marvel. The public will has decreed that houses shall be improved, that the milk supply shall be guarded, that medical advice shall be provided, and so forth.

The slow progress of reform

Yet it has all come through a process of gradual reform, and history will record no dramatic events, no groups of revolutionists defending barricades for the sake of the babies. Most people have no idea what has happened.

CHAPTER SIXTY-SIX

SOME GENERAL RESULTS

1. FROM our survey of the field of biology we observe : **Laws of life**

a. That life processes are governed by natural laws; that is, events follow each other in certain sequences, which can be observed and classified, and the results used as guides in estimating probabilities for the future.

b. These "laws," — in reality simply statements of what happens, — in all their more fundamental aspects, apply equally to animals and plants. We must therefore conclude that they began to operate at the dawn of life, and will do so while life exists. In other words, they represent the necessary activities of protoplasm.

c. Science does not reveal *all* these laws, and probably never will do so. The conscious mind transcends the phenomena in such a way that it is able to survey them as though from a place apart. It is a marvelous instrument, yet with limitations of many kinds, and it is impossible for it to know or understand more than a small part of nature.

Limitations of knowledge

d. Nevertheless, great advances in knowledge have been made, and greater will be made in the future. Reality is boundless, but truth is reality made manifest; the boundaries of truth are ever being enlarged. We speak of the *physical universe*, that which may be appreciated by our senses, may be observed and recorded, or made the subject of experiment. This is the subject matter of science. Beyond this is the *metaphysical realm*, into which we enter by reason of our imagination, postulating the unknown from the known. Here belong what William James called our "over-beliefs," which form the basis of our religion. The metaphysical field, as knowledge grows, is conquered by the

physical, and what was formerly incapable of "proof" is annexed by the outposts of science. Will metaphysics some day be abolished, dissolved in the ocean of positive knowledge? Will religion come to be wholly based on the rock of scientific truth? Not so; for outside of and beyond the area of metaphysics is a greater and wider realm of *metapsychics*, of reality which at present is beyond the reach of thought. This is easy to understand, when we think how much of the field of human thought is metapsychic for the dog, how much of the dog's for the jellyfish. As science extends its boundaries, so also the metaphysical field invades the metapsychical; and the human imagination, having gained the heights with a solid footing, uses this advantage to soar farther heavenward.

Duty to use the knowledge we have

e. Appreciating all our limitations, we yet see that the knowledge we have gained is sufficient to guide us in many ways, and give us innumerable advantages not possessed by people of earlier days. The failure to accept and utilize the gospel of modern knowledge is the great and deadly sin. For example, much of the misery and death of past centuries was due to causes beyond human control, but the recurrence of such events is today preventable. Our ancestors were not to blame for what they could not help; but we, who often could help and will not, must share in the condemnation of Cain.

Harmony

2. The purpose of such activities as we call religious, ethical, or progressive is to bring about greater *harmony* in the world of human affairs. This includes:

a. Harmony between human beings.

b. Harmony between man and his environment, or correct adjustment to environmental conditions.

The consciousness of harmony attained is *happiness*,

which is thus in a broad sense the object of our existence. **Happiness** It must be noted that harmony is a positive thing, not merely the absence of friction or discomfort. Hence man, having the maximum power of *feeling*, is capable of realizing the highest and greatest harmony, or happiness. By the same token, however, he is capable **Play the game!** of the greatest amount of misery; hence he is compelled to play his game, as it were, to the utmost of his strength, in order to realize the purpose of his existence. In the past, man suffered frightfully from his ignorance of the rules of the game; that is, of the processes of nature. His attempts to correct the evils he so keenly felt were valiant and persistent, but largely wasted through ignorance. He did not understand that he was to use his *mind* to ascertain how things happened; he was slow to learn by experience, because he did not understand his experiences. That intellectual and moral striving is the price of happiness is not the fanciful idea of some poet or philosopher, but a fact. Human life is necessarily dynamic. Error and sin consist in failing to play our part according to the rules of the game, either by breaking the rules or by failing to play up.

THE LAST LECTURE

Our course is run, our harvest garnered in,
And taking stock of what we have, we note how life,
This strange, mysterious life which now we hold and now eludes our grasp,
Is governed still by natural law, and its events
Tread on each other's heels, each one compelled to follow where the first has led.
Noting all this, and judging by the past,
We form our plans, until we know at last
The treasure in the future's lap.

The man, the plant, the beast, must all obey this law,
Since in the early dawn of this old world
The law was given, and the stuff was made
Which still alone can hold the breath of life:
Whereby we know that grass and man are kin,
The bond a common substance which within
Controls their growth.

Can we know all? Nay, but the major part
Of all that is must still elude our grasp,
For life transcends itself, and slowly noting what it is,
Gathers but fragments from the stream of time.
Thus what we teach is only partly true.
Not knowing all, we act as if we knew,
Compelled to act or die.

Yet as we grow in wisdom and in skill
The upward path is steeper and each step
Comes nigher unto heaven, piercing the clouds
Which heretofore have hid the stars from view.
The new-gained knowledge seems to fill the air,
It seems to us the soul of truth is there.
Our quest is won.

Bold climber, all that thou hast won
Lies still in shadow of the peaks above;
Yet in the morning hours the sun
Rewards thy work of love,
Resting a moment on thy lesser height,
Piercing the vault with rays too bright to face,
Strengthens thy soul and gives thee ample might
To serve thy human race.

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